JUNE 1959

JOURNAL OF THE IRON AND STEEL INSTITUTE

4 GROSVENOR GARDENS · LONDON SWI

Established 1869 · Incorporated by Royal Charter 1899

VOL. 192 PART 2

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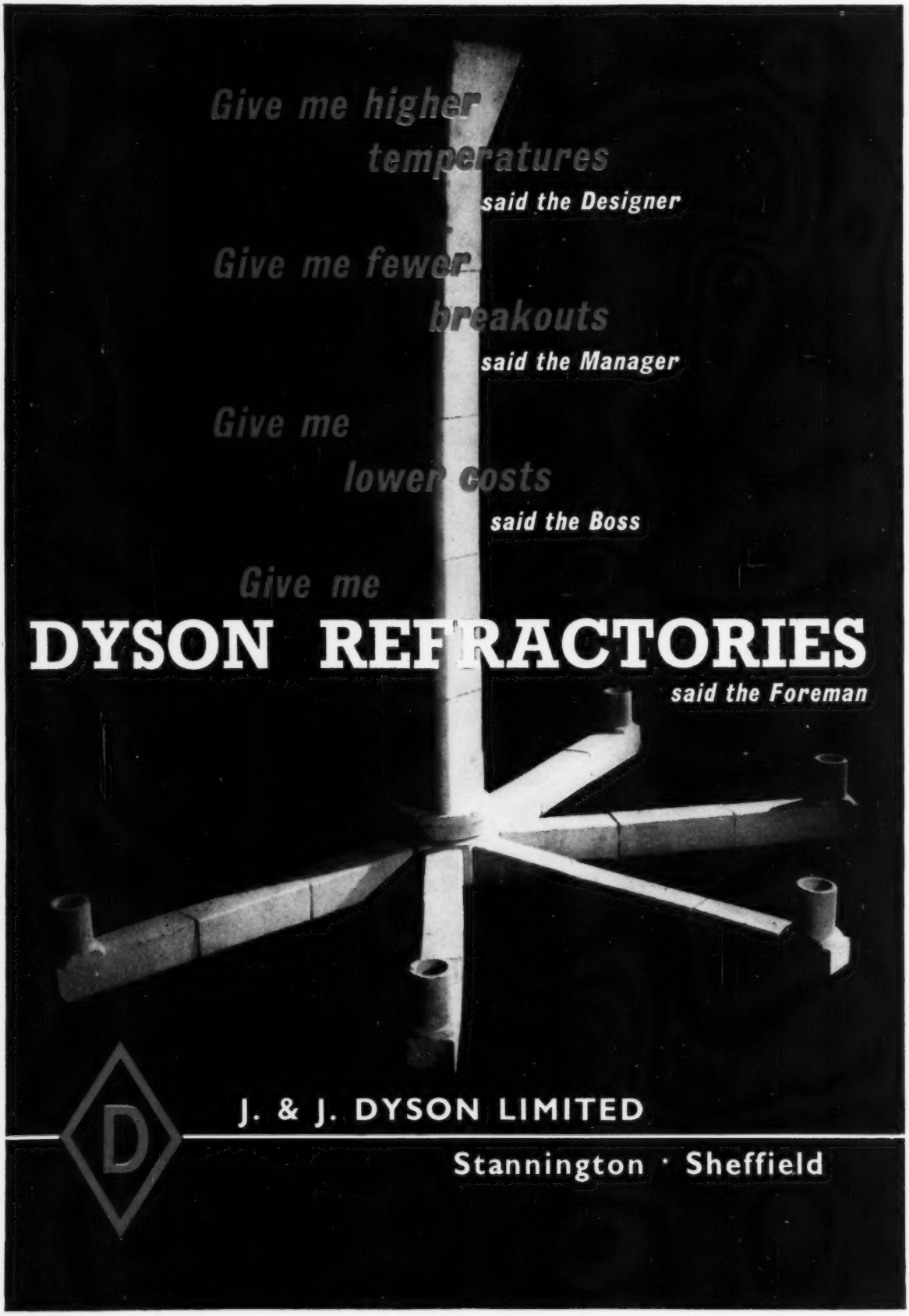
Give me higher temperatures
said the Designer
Give me fewer breakouts
said the Manager
Give me lower costs
said the Boss
Give me
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Marking a new departure in the practical field of oxygen steelmaking, this 20 ton unit for refining blast furnace metal was designed, in collaboration with the Brymbo Steel Works, and constructed by Wellman.

Refining is effected by injecting oxygen and powdered lime, through automatically controlled lances, into the bath.

The vessel has provision for:— slagging, adding scrap and fluxes, fettling, and sampling during operation.

This is a further example of Wellman activities in providing designs and equipment for new steelmaking techniques involving the use of tonnage oxygen.

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Conference on X-Ray Analytical methods

A conference will be held on X-Ray Diffraction and Spectrography in conjunction with the Department of Chemistry at Imperial College of Science and Technology, London, S.W.7; from Monday, 6th of July to Friday, 10th of July, inclusive. The conference will discuss and evaluate modern techniques and instrumentation for Diffractrometry and Fluorescent Analysis. An extensive range of modern equipment will be available for demonstrating the principles of these methods over a wide field of applications.

Time will be made available for the consideration and study of samples submitted by members. Sample preparation and presentation together with the use made of electronic analytical information will be discussed in relation to the requirements of industry.

Full information concerning the conference together with detail of registration fees may be obtained from the Conference Secretary at Research and Control Instruments Limited, Instrument House, 207 King's Cross Road, W.C.1, to whom all enquiries and applications should be addressed.

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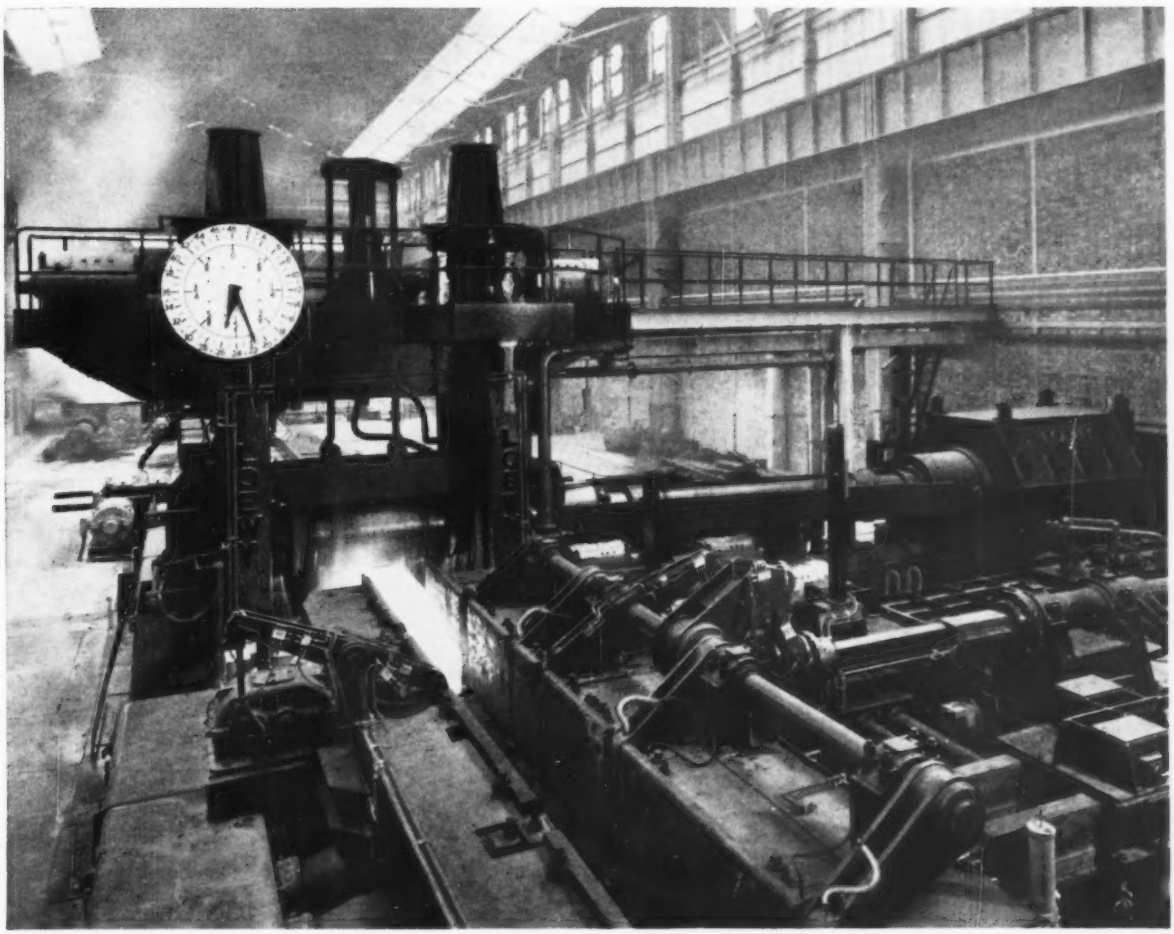

We also supplied a complete Plate Rolling Mill Plant with 98″ 4-High Mill Stand to this customer.

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BOURNEMOUTH ENGLAND

At your Service...

This man is one of the Foster Instrument Company's Service Engineers. He is just setting out on an emergency call to a large engineering works in the Midlands where a breakdown has been reported. He will travel over fifty miles, find the fault, set the equipment working again and be on his way to a regular service Contract appointment after lunch. That call will have cost the customer a worrying few hours, a stoppage of production and lost time for several operatives — and it could well have been avoided by using the Foster Service Contract Scheme.

Briefly this scheme, which has been in successful operation for over 20 years, covers periodic visits by our Service Engineer to examine, adjust and certify (to A.I.D. requirements) the accuracy of our temperature measuring equipment. The visits can be arranged at 3, 6 or 12 monthly intervals according to the customers' requirements and the charges are very reasonable. If you use Foster instruments do write to us for details of this scheme — wherever you are in England, Scotland, Wales or Northern Ireland.

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★ *a view of the cab showing the seat control unit.*

The Adamson 50/10 ton crane is the third of a series of new design supplied to Richard Thomas & Baldwins Limited, Ebbw Vale Section. Features of the crane include monolithic construction of the crab and the elimination of castings by mild steel fabrication of the hoist barrel and bottom block. The cab is of particular interest as it incorporates the most modern type of seat unit ensuring maximum vision and ease of control. Joseph Adamson electric overhead travelling cranes can be supplied to all specifications including cranes suited to the most exacting 24 hours-a-day process work.

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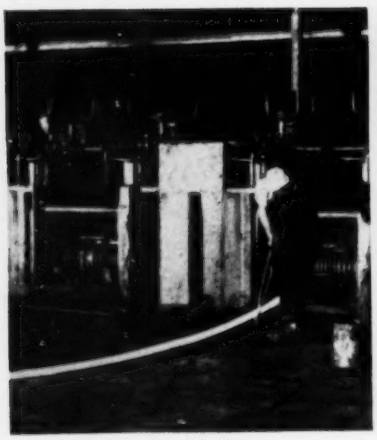

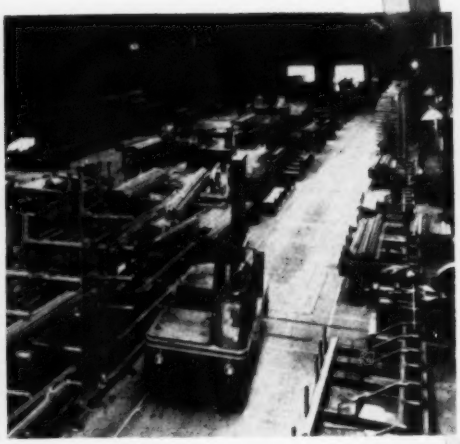

Makers of Precision Ground Bars in many qualities of Carbon and Alloy steels to tolerances varying from .00025″ to .001″ ±, as specified. Centreless Turned and Cold Drawn Bars are also supplied, the former to limits ± .004″ and the latter to limits ± .002″.

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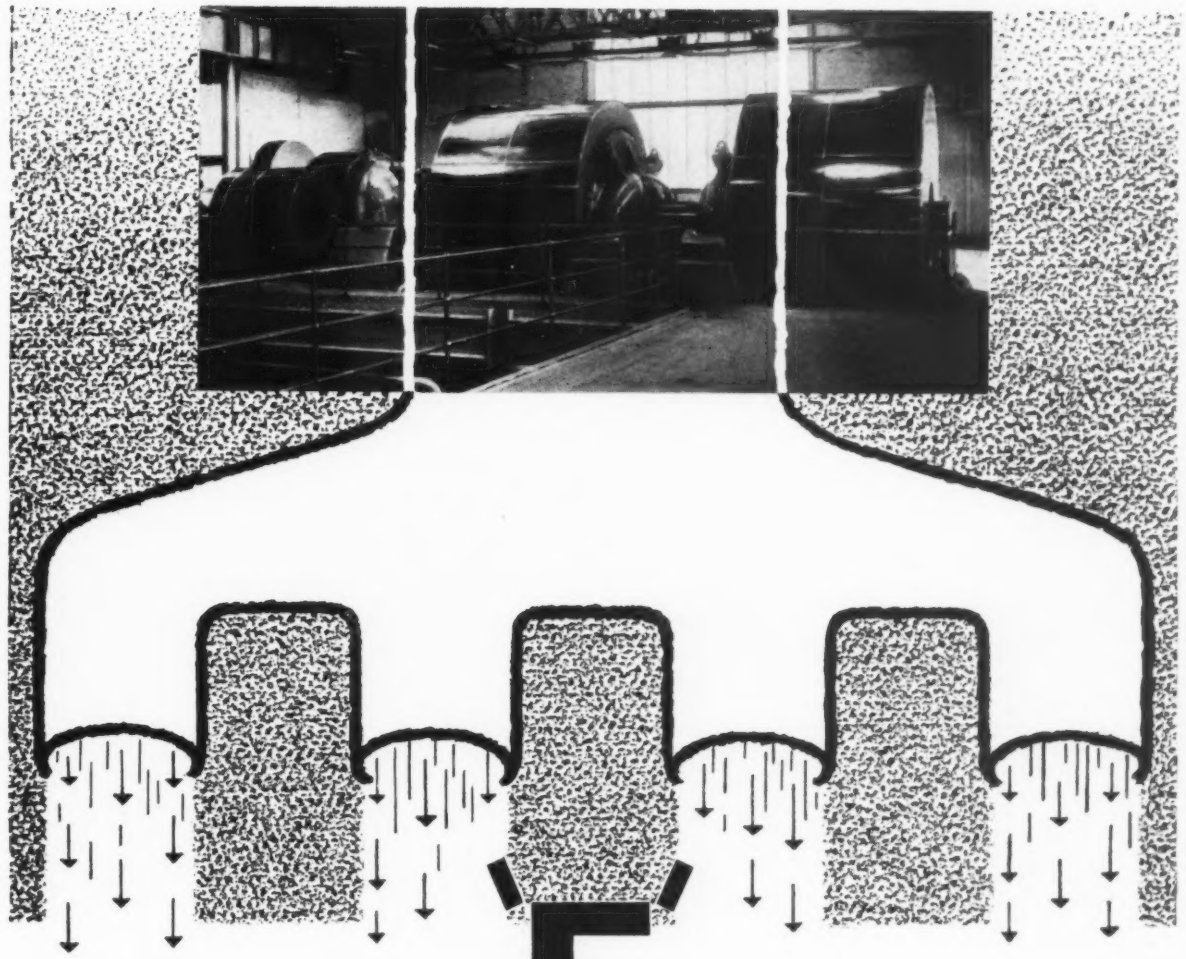
River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd.



GIANT 'E' BLOWS

The world's largest turbo-blower was built and installed by Parsons at the Scunthorpe Works of the Appleby Frodingham Steel Company Branch of the United Steel Companies Limited.

Known as the 'E' Blower, it is designed to supplement the output of the four smaller turbo-blowers, also built and installed by Parsons, or to act as a separate unit blowing air direct to any one, or two, of the four blast furnaces at this modern iron works.

PARSONS

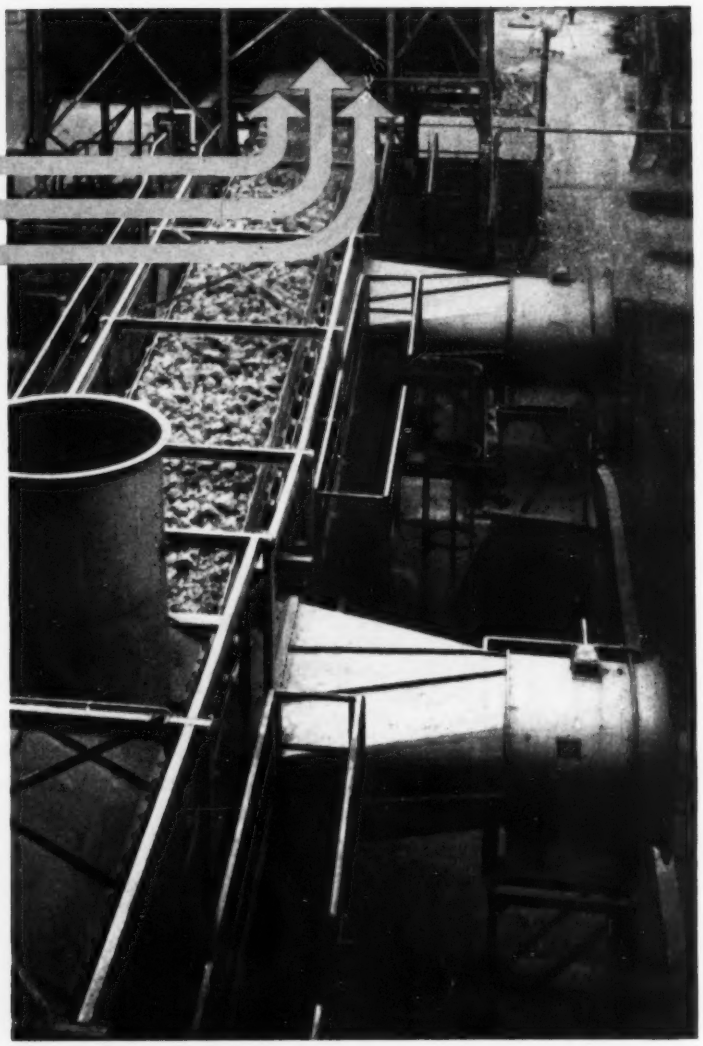
TURBO-BLOWERS

'E' Blower is capable of delivering 160,000 cubic feet of free air per minute at a pressure of 35 lb. p.s.i.

C. A. PARSONS & COMPANY LIMITED · HEATON WORKS · NEWCASTLE UPON TYNE 6

SPEEDING THE SINTER FLOW

This photograph was taken looking down on the sinter conveyor at Barrow Ironworks. On the right of the conveyor can be seen two of the three fans which have reduced the cooling interval so efficiently.

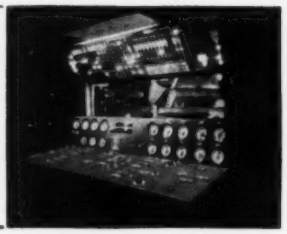


For 70 years, we have made steady improvement of the sintering process our business, and each sinter plant we design and install incorporates the latest developments in sintering technique.

At many new sinter plants, including those at Barrow Ironworks, Consett Ironworks, the Iron and Steel Corporation of South Africa, Cockerill-Ougrée (Belgium) and the Société Métallurgique de Normandie (France), a new Huntington Heberlein cooler has increased the efficiency of the sinter process. High quality sinter is being cooled in 20 minutes from 600°C for transmission on normal belt conveyors. This cooling is achieved by forced circulation from cold air fans which work at very low power consumptions.

Associated in the U.S.A. with Koppers Company Incorporated, our other specialities include: Ore Dressing Plants, High Intensity Magnetic Separators, Herreshoff Furnaces and Badische Turbulent Layer Roasters.

The feed rate control panel at Barrow



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HH29

The Barber, Engraving by A. Bosse, circa 1640.

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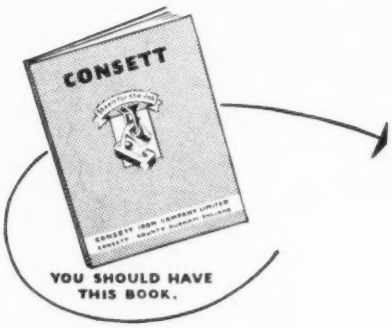
Every man to his own trade –

... and our trade is STEEL!



Not only mild steel for everyday use but also the special steels demanded by the Nuclear Age . . . for example we produced the special steel plates for the reactor vessels at Calder Hall, Chapelcross and Bradwell and now we have been entrusted with the production of the plates for the nuclear power station reactor at Latina, Italy.

An interesting booklet "Steels for the Job" just published by us, describes some of our newer products. We shall be delighted to send you a copy.

Our technical and research department will also welcome enquiries from any whose problem is . . . **STEEL**

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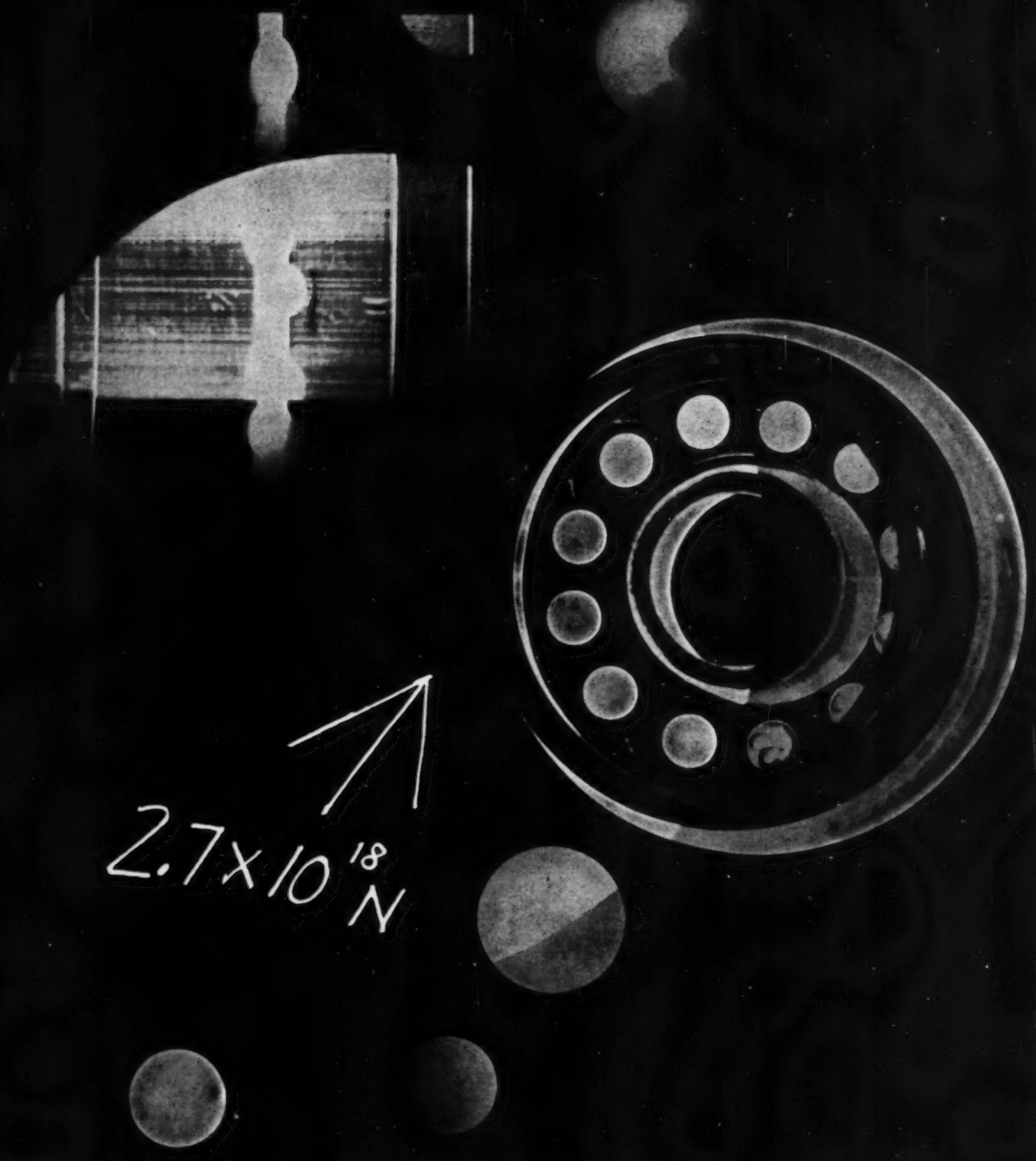
APL greases passed



the final test...

Radiation broke up the gel structure of conventional greases. They lost their lubricating properties, turned fluid or granulated. Completely new kinds of greases were needed by the atomic power industry for the bearings situated within the radiation field.

The Shell Group started working out radiation-resistant APL greases whilst most nuclear power stations were still on the drawing-board, and the research that went into them is characteristic of the way Shell set about doing things.

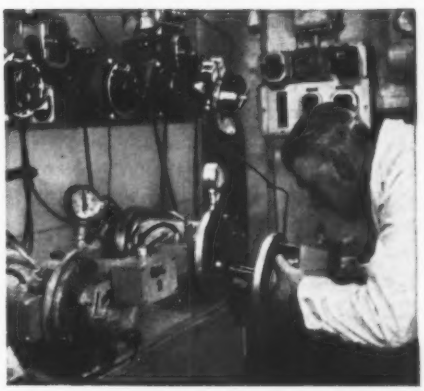
A team of research workers was assembled at Shell's Research Centre at Thornton. After four years of research and testing – both at Thornton and the A.E.R.E. Harwell - APL greases were ready for their finals. A sample was packed into a bearing and sunk into the B.E.P.O. pile. There it was not only subjected to mechanical working and high temperatures in CO_2, but also to an integrated pile dosage of 2.7×10^{18} thermal N. per sq. cm. plus associated radiation. APL greases sailed through their finals – and Shell are proud of it. They should be. For with these greases, Shell completed Britain's first range of Atomic Power Lubricants.

The moral of the APL story is that Shell research is supremely applicational. The Centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right lubricant for the job. If you and your organisation have any major lubrication problem, it will pay you to get in touch with your local distributor of Shell Industrial Lubricants.

The Research Story

Naturally a whole variety of greases were investigated. Conventional metallic soap greases were affected even by relatively low levels of radiation. Other greases based on synthetic and non-petroleum materials were examined and found to be equally unstable. Some of them softened appreciably and became tacky, whilst others hardened.

The Shell APL 700 series of greases are specially processed with an inorganic gelling agent, the base lubricant used being similar to the APL oils previously proved highly resistant to radiation. There were three series of tests. First tests were preliminary radiation tests at Harwell. Then the greases were tested for their lubricating qualities in a high temperature (400°F) pressurised CO_2 anti-friction bearing rig turning at 1,500 r.p.m. For the final tests, actual working conditions were simulated at Harwell.



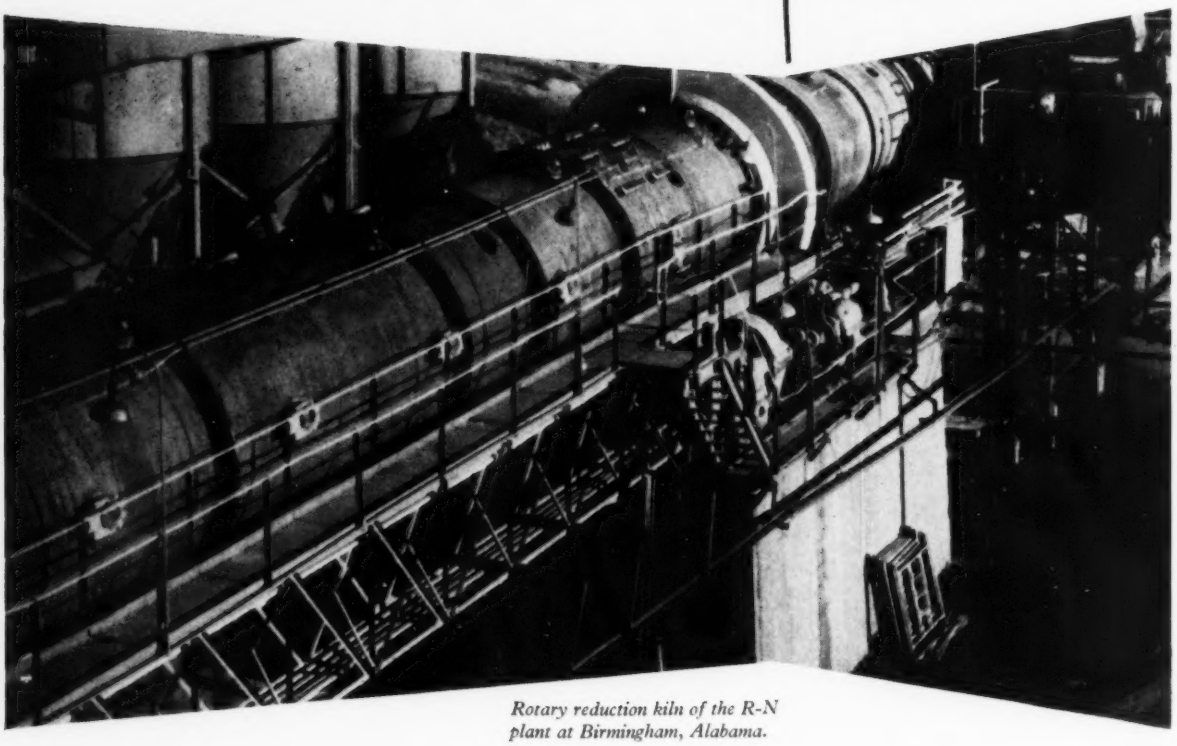
SHELL

ATOMIC POWER LUBRICANTS

another proof of Shell leadership in lubrication

THE R-N PROCESS

for direct reduction of iron ore and subsequent wet separation of gangue



Rotary reduction kiln of the R-N plant at Birmingham, Alabama.

R-N Product replaces pig iron as well as scrap

The R-N Process provides the world's steel industry with a new steel furnace feed material from ores of nearly all types by direct reduction utilizing various types of solid, low-cost fuel and surplus gas if available.

The wet magnetic separation after reduction removes the ore gangue and the concentrate obtained contains usually more than 90% Fe as metal, less than 3% SiO_2 and only a smaller part of the phosphorus of the ore.

The sulphur content of the concentrate is below 0.05%.

The concentrate is dried and formed into briquettes.

The capital cost of an R-N plant is about half that required for a blast furnace complex of corresponding size, and the production cost for R-N metallic iron briquettes will be considerably lower than that for pig iron.

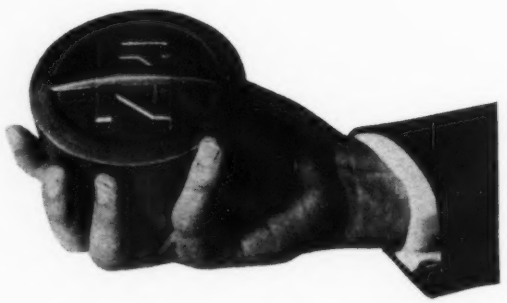
Low stable price and uniform composition make R-N iron an excellent and competitive substitute for scrap.

The development of the R-N process to a commercial process is the result of collaboration between the Republic Steel Corporation and the National Lead Company through the R-N Corporation, New York.

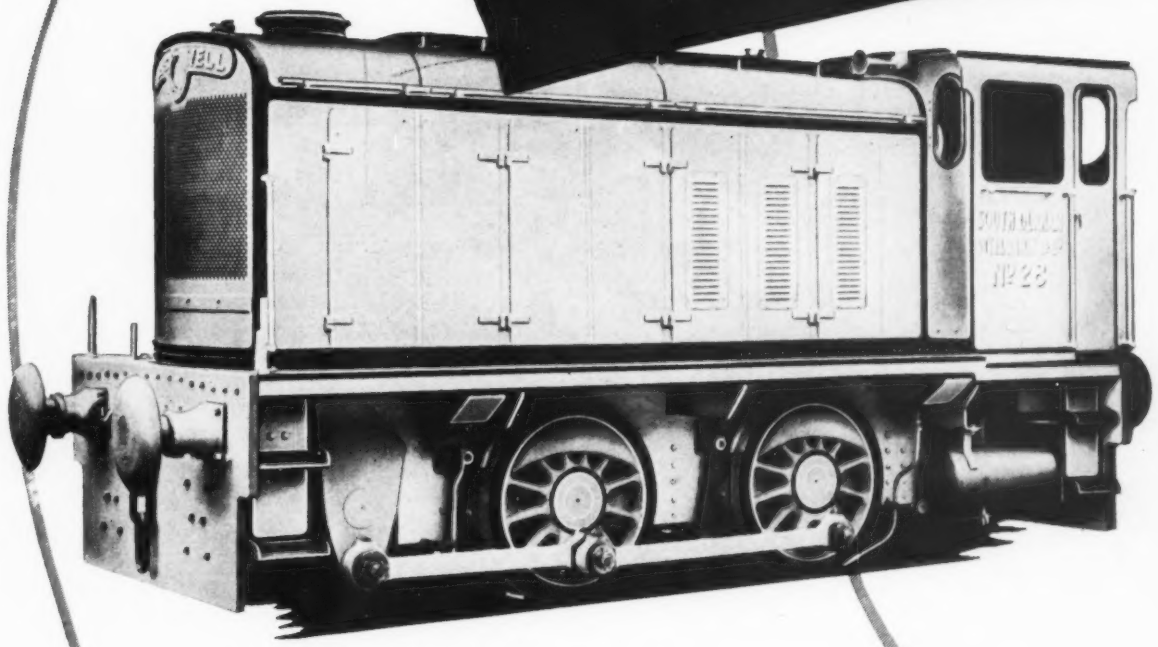
Representative for Europe:

R-N PROCESS AGENCY

162, Avenue Louise,
Brussels.
Tel: 48.81.30



British Engineering at its best



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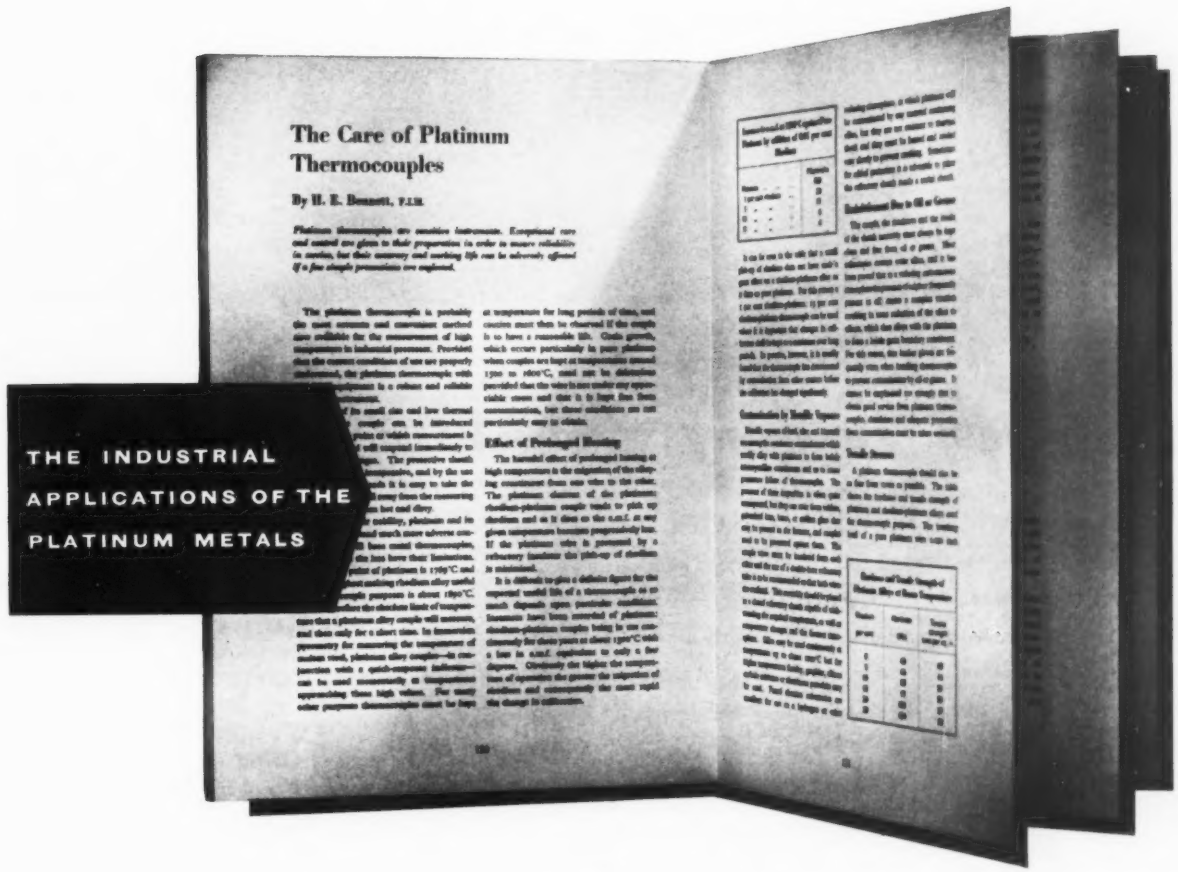
Platinum Metals Review

A quarterly survey . . .

In recent years the industrial consumption of the platinum metals has increased so rapidly that today nine-tenths of all platinum production is absorbed by industry. To provide research workers, engineers, chemists and metallurgists with up-to-date information, "Platinum Metals Review" is published quarterly. May we add your name to our mailing list?



Information regarding the properties of the platinum metals and their industrial applications is freely available.

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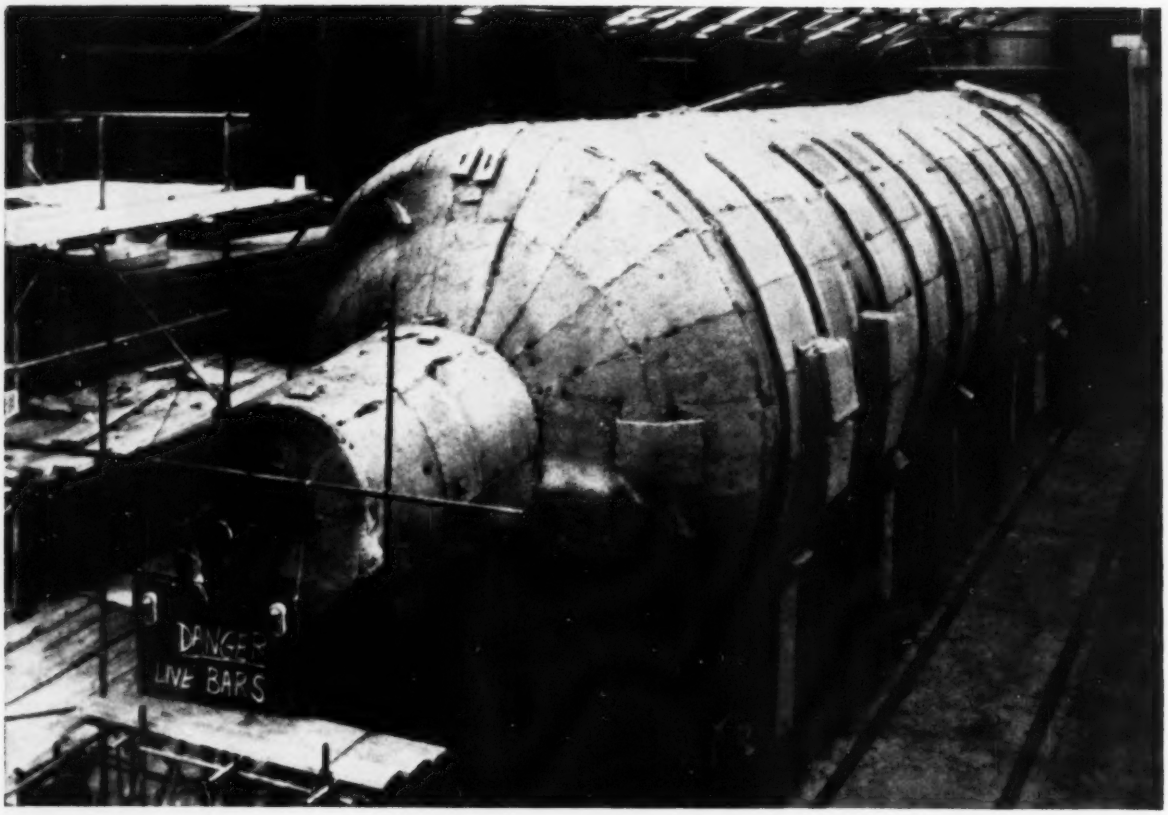

Stress relieving of a heat-exchanger for Bradwell Nuclear Power Station carried out at the Thornaby-on-Tees Works of Messrs. Head Wrightson, Teesdale Ltd.

Stress relieving of LARGE VESSELS

A MODERN TECHNIQUE

Above is an example of this technique. The 95 ft. long heat exchanger is totally covered with Stillite SR10 semi-rigid slabs and mineral wool mattresses. The heat is applied within the vessel by means of electric resistance elements disposed to give uniform heat. In this instance stress relieving temperature was attained in only *25 hours*, and the soaking temperature maintained.

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★ Stress relieving can be carried out on site thus solving the problem of transporting large vessels.

★ Saving in Capital Investment—no outlay required for a large permanent furnace structure.

★ Saving in heating costs. Relieving temperature quickly attained because of the low heat capacity of the enclosing insulation.

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1 The entry friction guides are rigidly clamped into the guide box. They are intended to lead the oval to the groove in the roller, to protect the rollers against overloading, and to straighten bent rods.
The groove in the entry guides is made about 1/8" wider than the oval.

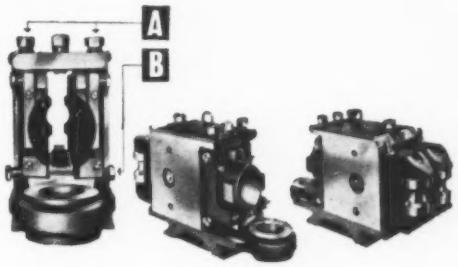
2 The rollers are mounted on leaf springs, which can be adjusted by means of the screws "B", and hold the oval steadily even if there should be some slight variation in the thickness of the oval.

3 If the thickness of the oval should vary, the springs of both rollers yield an equal amount, so that the oval remains in the centre of the groove.

4 To tilt the oval, the screws "A" are adjusted. One roller will then be lifted as much as the other is lowered.

5 As the oval is held very rigidly, the leader oval for wire rod may be thick, unless other circumstances call for a thinner oval.

6 The roller guide assemblies are narrow, and all screws that require adjustment during rolling are accessible from the front of the mill. No lateral space outside the guide box is therefore required for gaining access to the set screws, and the guide box assembly can thus be located close to the mill housing.



7 As the groove in the entry guides is wide and nothing but rolling friction acts on the oval, the latter is very easily introduced into the pass, and there is practically no risk of scratching the bar.

8 The roller guide may be used not only for leader and drawing oval passes but also for edging flats as well as for rolling squares, hexagons, octagons and various other sections, for instance in reduction passes for hexagon. It is suitable for all types of rolling mill. An important advantage is that the roller guide enables repeaters to be used in rolling plump leader-ovals.

PS *Practically speaking, every bar and wire rod mill in Scandinavia uses roller guides of our design.*

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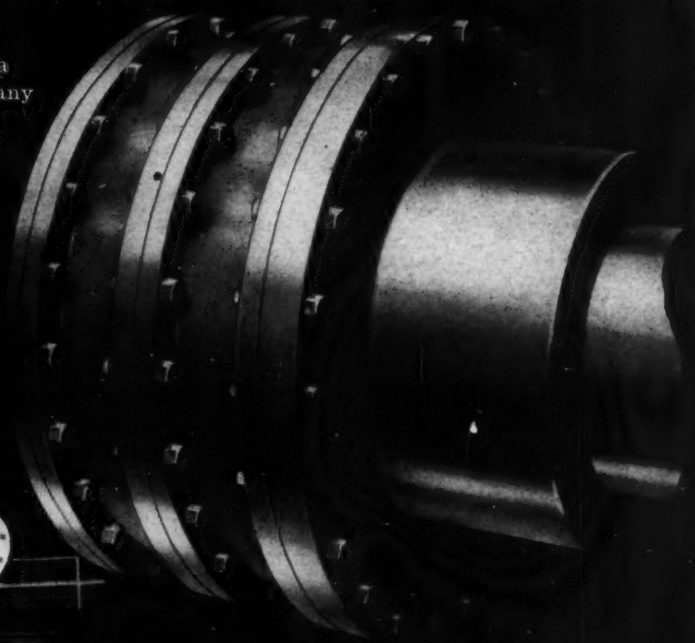
HOLSET FLEXIBLE COUPLINGS

Holset Flexible Couplings are giving a highly satisfactory performance in many leading steel works and are specified for their important characteristics:—

1. Ample torsional resilience.
2. Capacity to absorb shocks, torque fluctuations and accommodate substantial shaft misalignment.
3. Noiseless operation and absence of maintenance and lubrication.
4. Maximum protection to both prime mover and driven machine, hence lowest overall maintenance costs.



The Coupling illustrated transmits 21,000 H.P. at 40 r.p.m. to a Reversing Slabbing Mill.

Small coupling diameter means a low WR^2—a very important factor in reversing mills—shafts up to 32" diameter can be accommodated.

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C.3643

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That's where our long experience with the Furnace Industry benefits customers—they use us as an advice bureau—and we like it! Our cast Nickel Chrome carburizing boxes are in constant use in heat-treatment plants throughout the country.

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Where even the smallest foreign particle may imperil life, nothing is left to chance. Complex units, such as engine oil coolers which cannot be dismantled for inspection, are therefore radiographically examined to detect accumulations of sludge, metal debris, and carbon particles which would spell danger if they circulated in the engine lubrication system.

For this examination, British Overseas Airways Corporation relies on ILFORD Industrial B X-ray film. Ilford has a reputation for reliability.

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HAS IT DAWNED

THAT STEEL CASTINGS ARE QUICKEST AND CHEAPEST •

When designing —think of castings first.....

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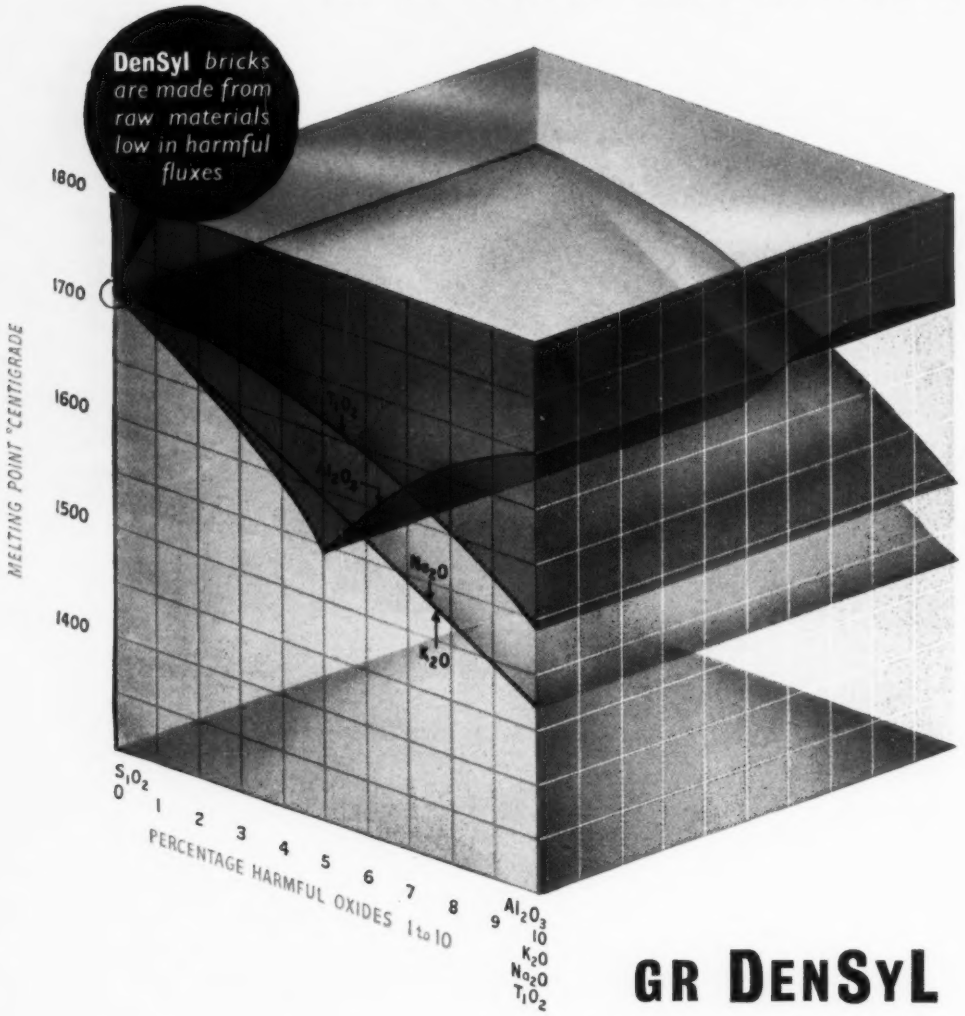

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Glass tank roofs.

Glass tank super-structure.

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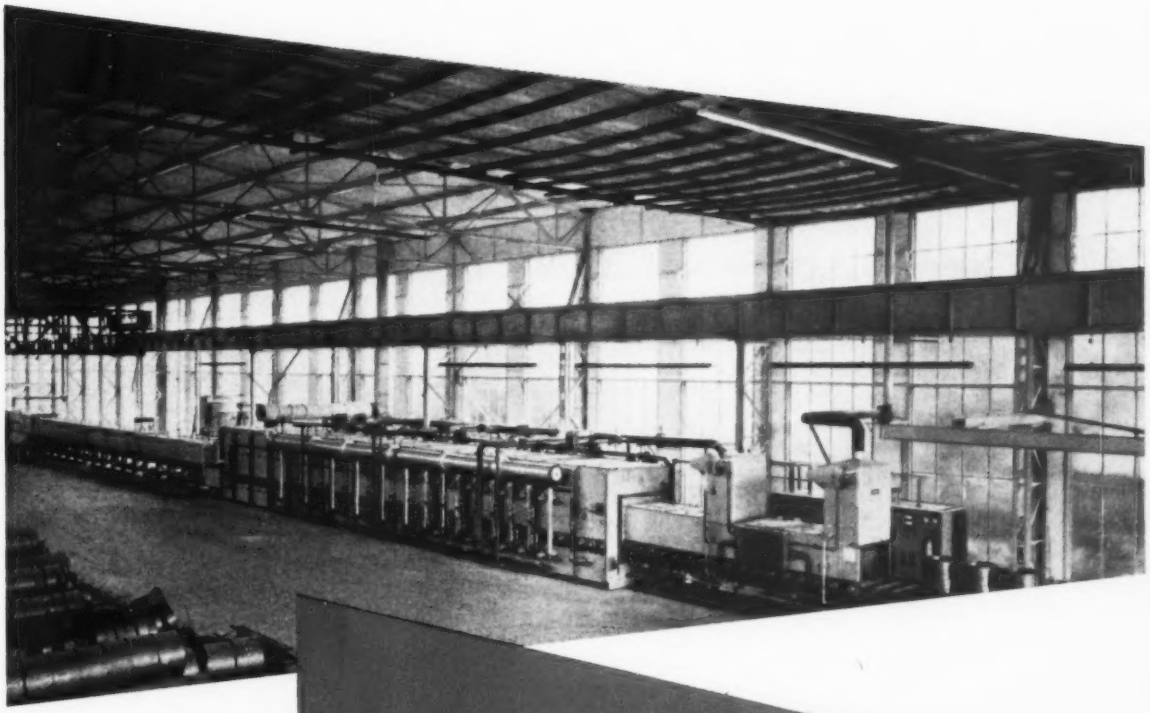

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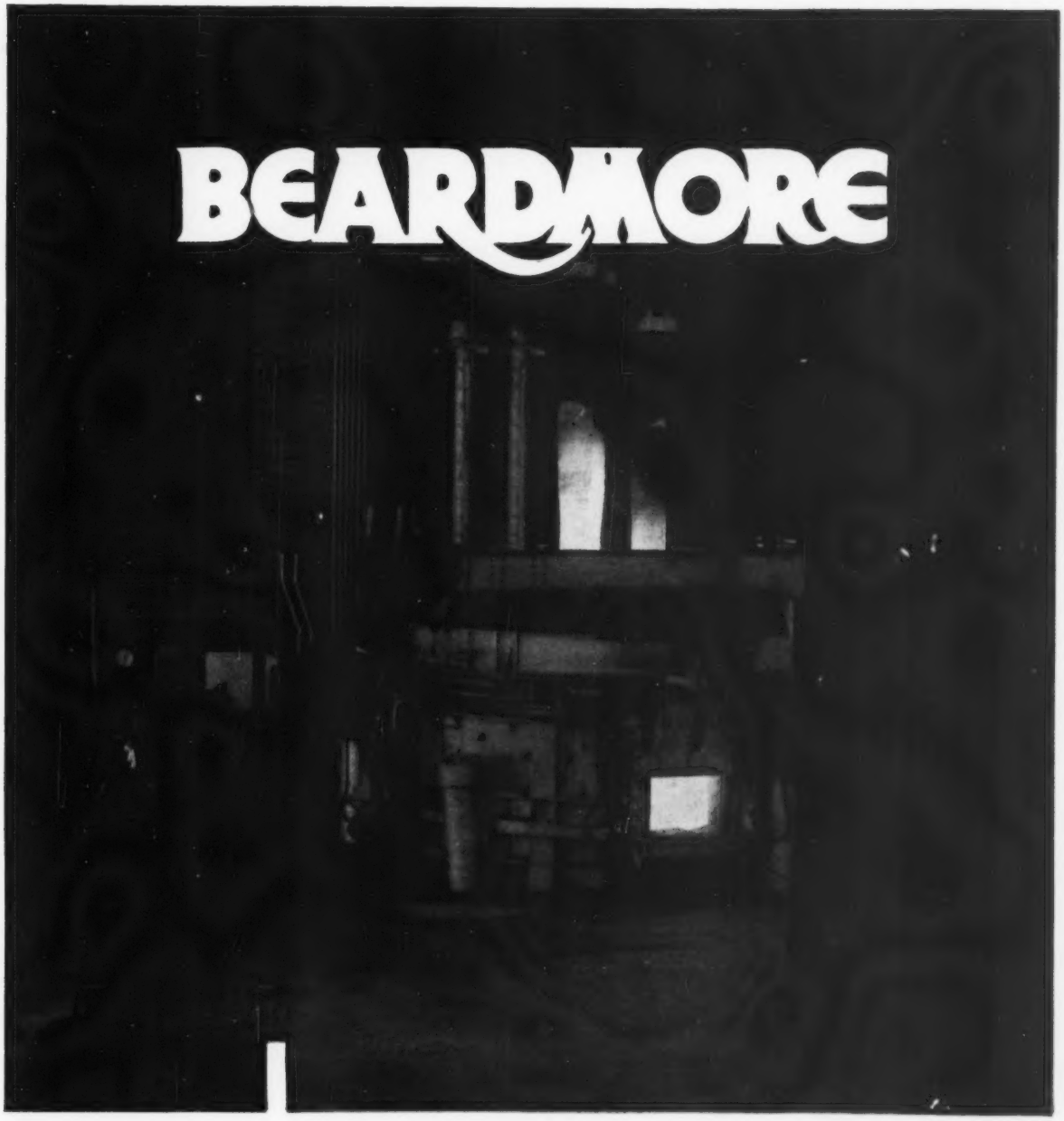

Among the latest developments at Parkhead Steelworks, Glasgow is the 80-ton Electric Arc Melting Furnace shown above.

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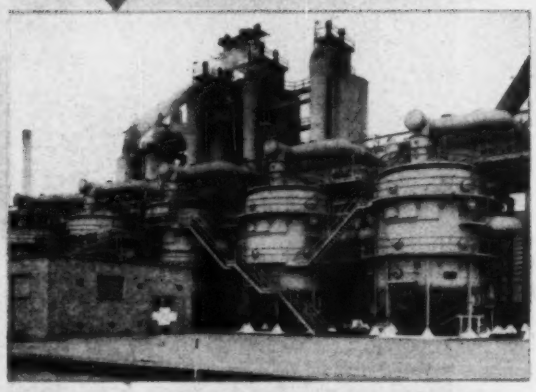
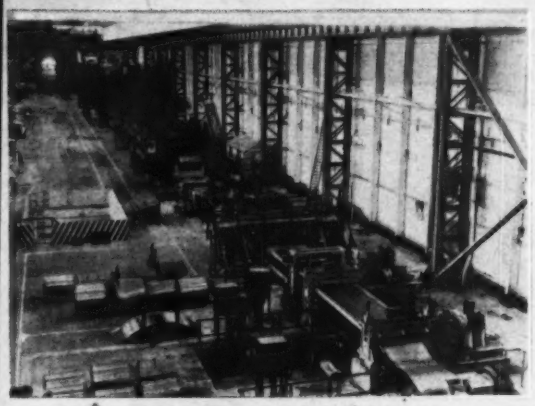
Gas cleaning plant for the Appleby – Frodingham. Steel Co.



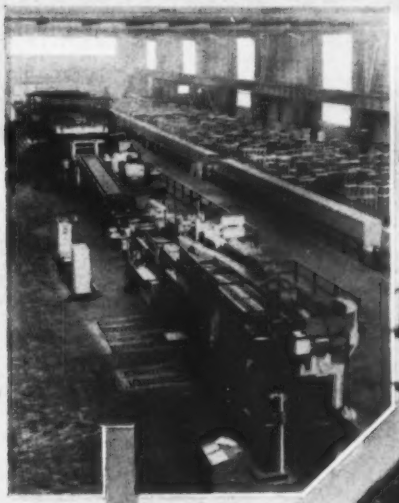
Blast furnace for the Empresa Nacional Siderurgica S.A. at Aviles in Spain. The furnace hearth is 27 ft. in diameter.

WRIGHTSON

services for the steel industry



The largest and most modern continuous galvanizing plant in Britain at the Ebbw Vale works of Richard Thomas & Baldwin Ltd.



Electrolytic tinning line at the Velindre Works of the Steel Co. of Wales.

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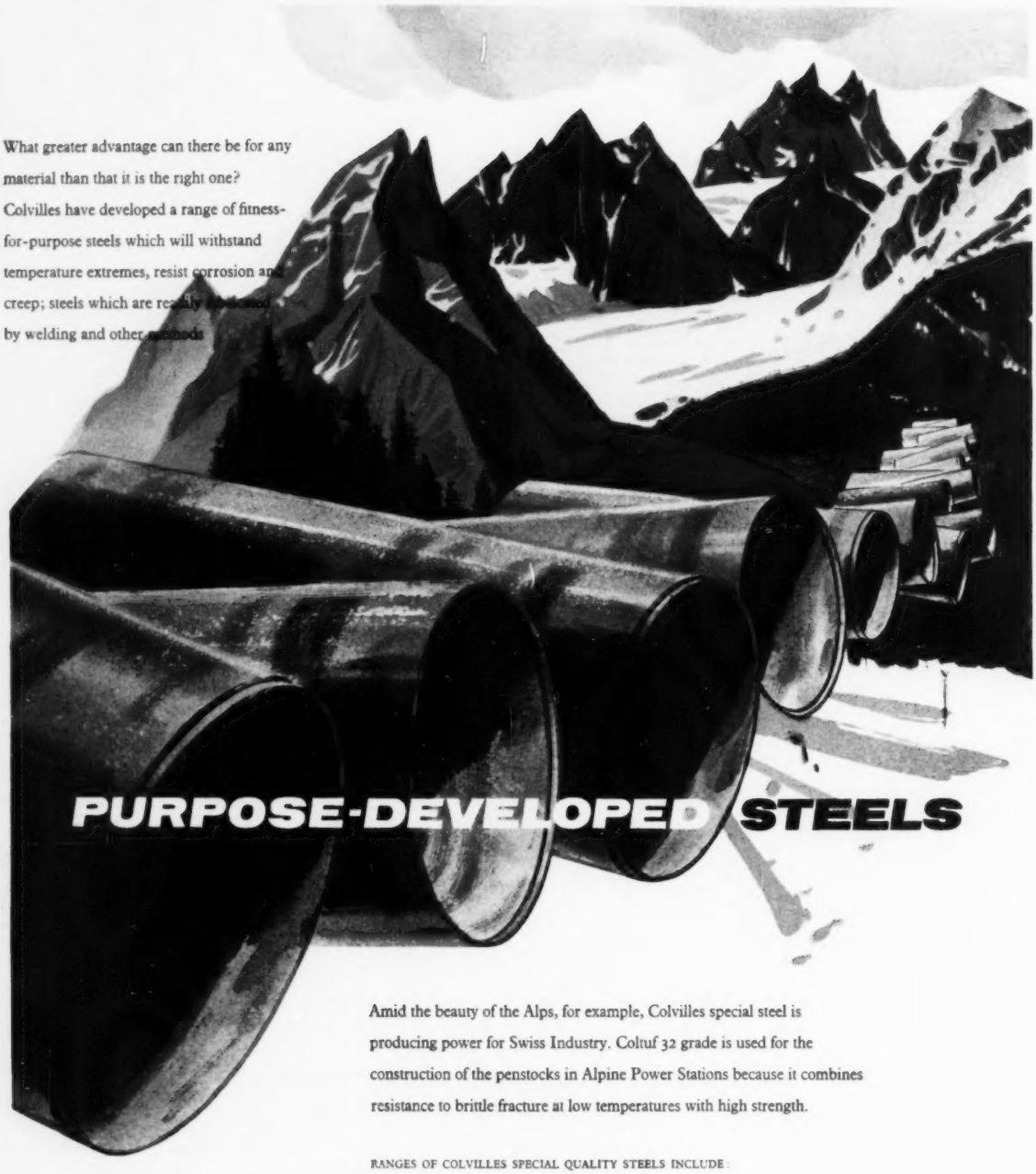

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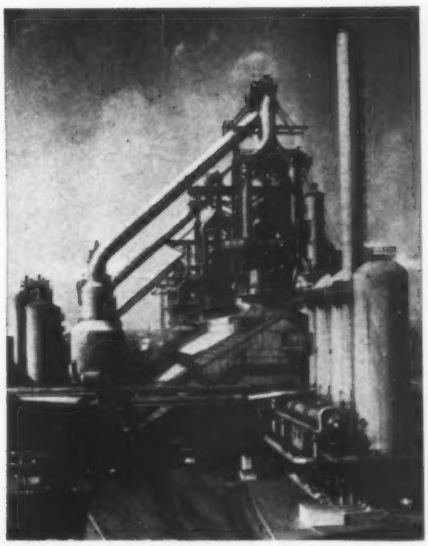

Photograph by courtesy of the Appleby-Frodingham Steel Company, Scunthorpe (branch of the United Steel Companies Limited)

Over 140 CARBLOX Blast Furnace linings throughout the world

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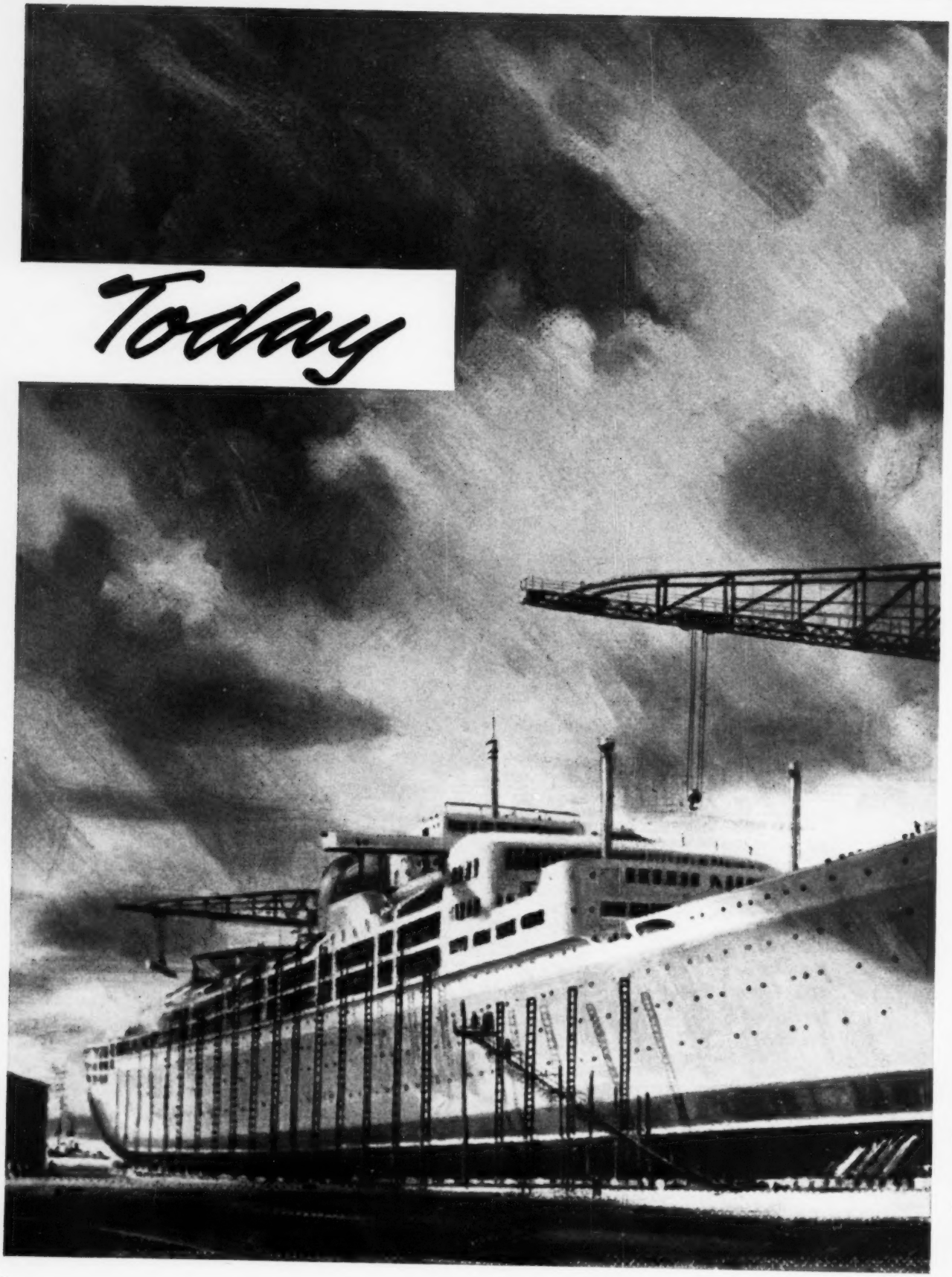
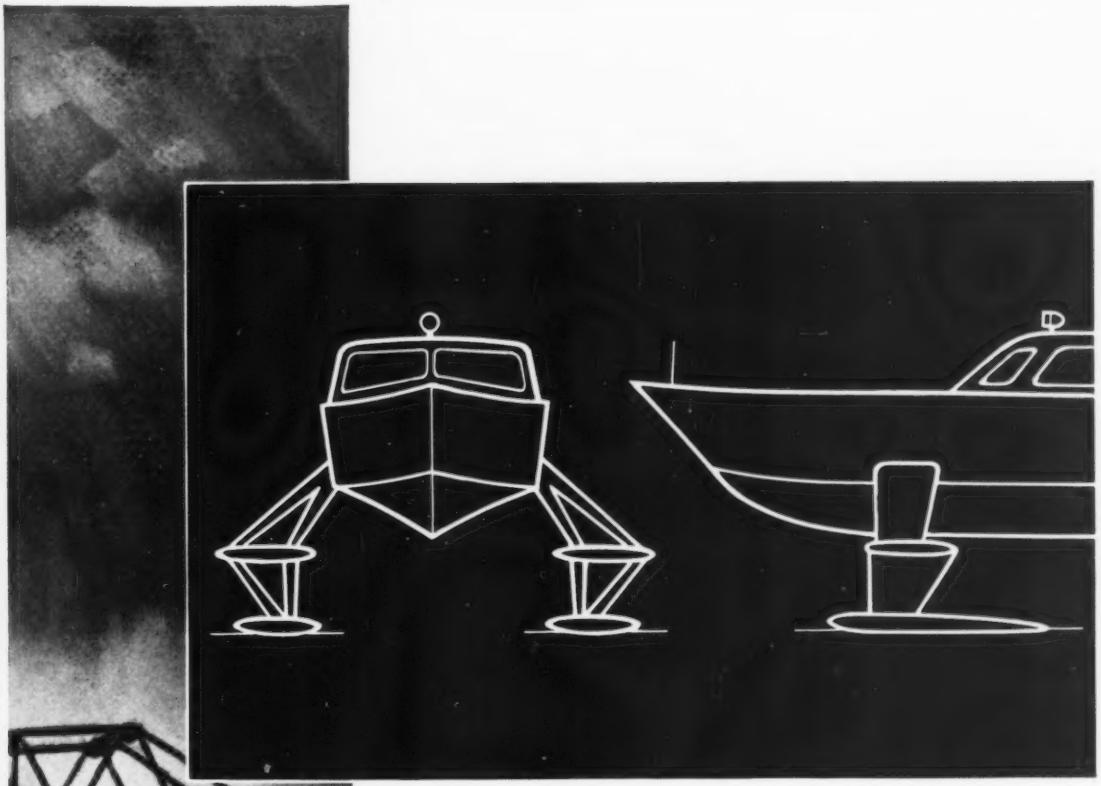

Today



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Today gas is *the* fuel in forging, annealing, rivet heating and other basic heat processes in shipbuilding and heavy engineering; gas also has specialised applications such as drying before shot blasting. Industrial Gas research and consumer service ensure that tomorrow gas will be Britain's most economic fuel . . . **AND TODAY**— every industry and 12 million homes use **GAS.**

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4" Holmes-Western Valve.
Typical of valves
3" and 4" bore.

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From 3" bore to 48" bore

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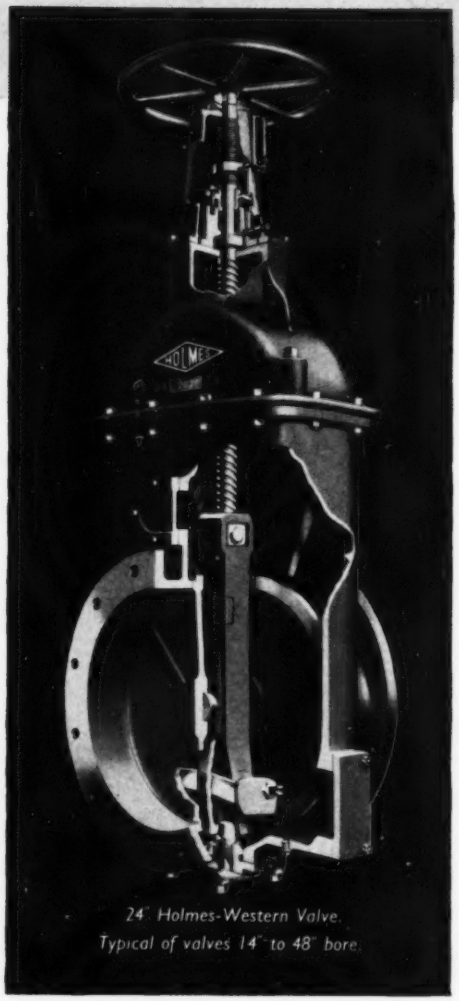

24" Holmes-Western Valve.
Typical of valves 14" to 48" bore.

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Save costly metal replacement, and beautify as you protect, with famous Rust-Oleum made in United States of America. If the surface is rusty — apply Rust-Oleum 769 Damp-Proof Red Primer right over the sound rusted metal — after scraping and wirebrushing the rust scale and loose rust away. The *specially-processed* fish oil vehicle penetrates rust to bare metal — driving out air and moisture. It dries to a tough, firm, decorative finish that lasts and lasts. Proved throughout American industry for over 35 years. You save costly metal — and you save costly surface preparations as sandblasting and chemical cleaning solutions are usually eliminated.

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Rust-Oleum finish coatings are available in Red, White, Gray, Blue, Green, Black, Aluminum, Yellow and many other colors. Used over the Rust-Oleum 769 Damp-Proof Red Primer — they provide the maximum in lasting beauty on tanks, pipes, towers, girders, equipment, machinery, stacks, metal fences, sash, boilers, and other rustable metal. The Rust-Oleum distributor listed below maintains complete Rust-Oleum stocks for prompt delivery to you. He welcomes the opportunity to tell you about Rust-Oleum and will be happy to provide you with a complete Rust-Oleum Color Catalog and a free test sample. Ask him for a demonstration on your own rusty metal.

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- ☐ Please have your representative call to give me a Rust-Oleum demonstration.
- ☐ Finish Color desired in FREE TEST SAMPLE —

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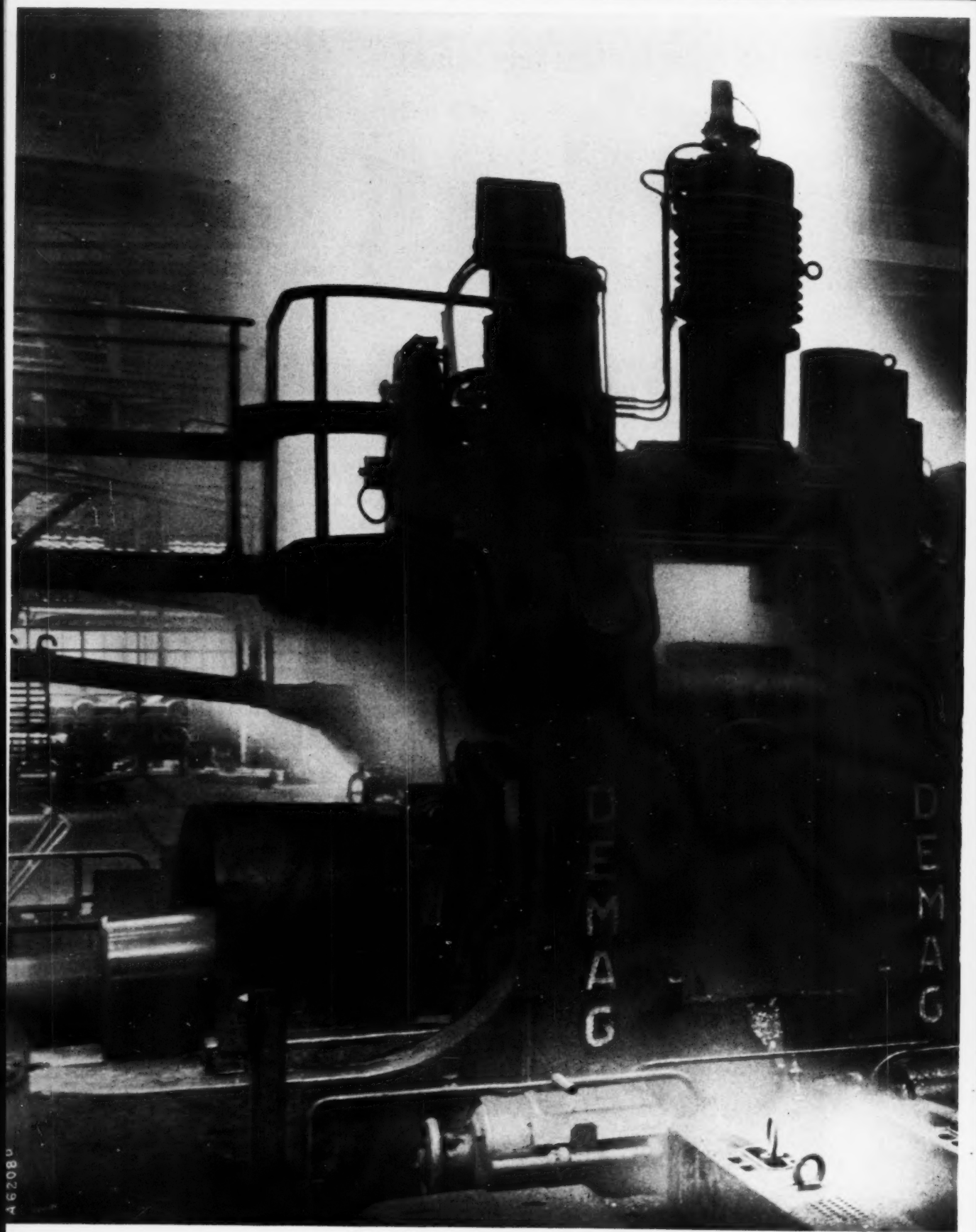
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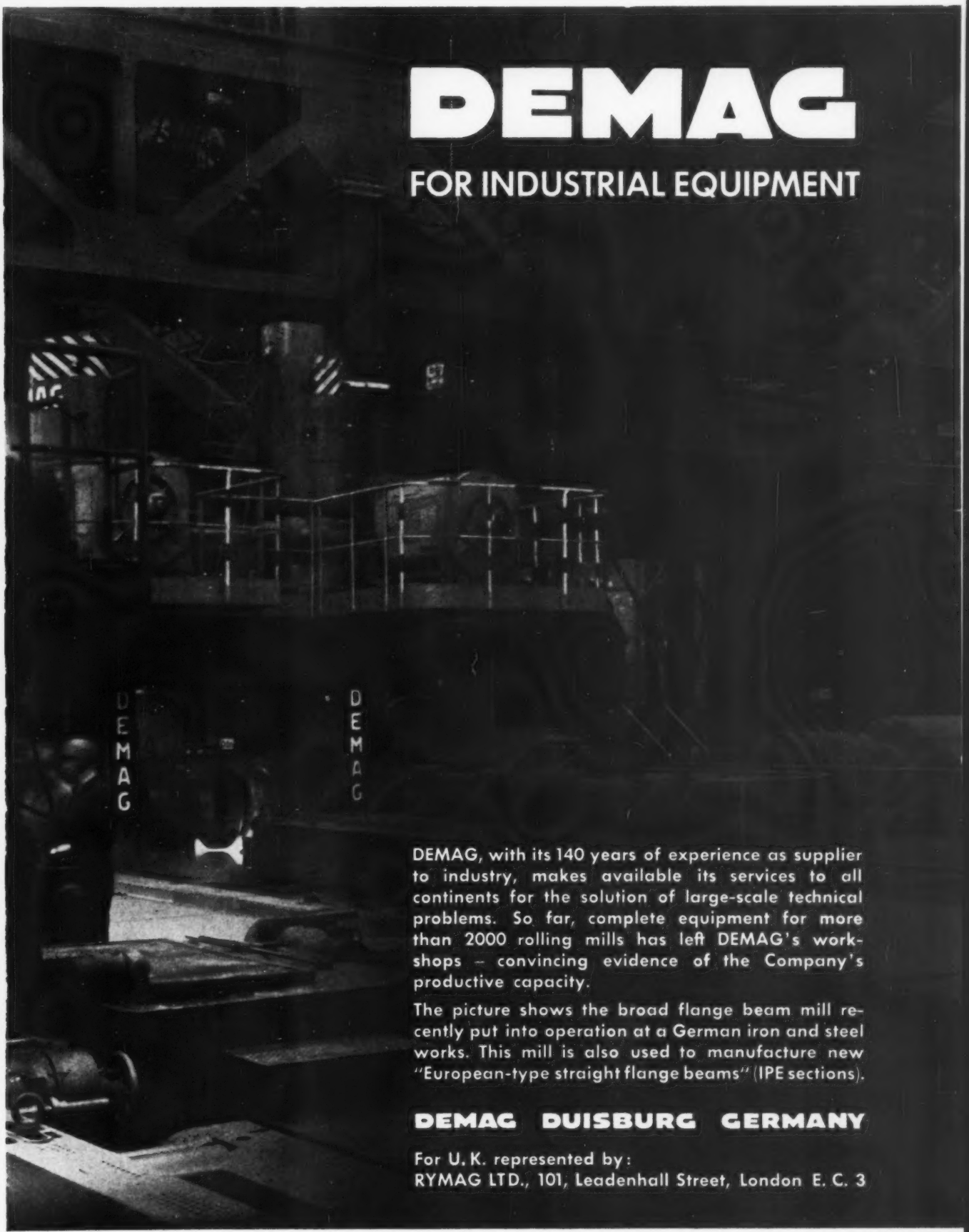

DEMAG, with its 140 years of experience as supplier to industry, makes available its services to all continents for the solution of large-scale technical problems. So far, complete equipment for more than 2000 rolling mills has left DEMAG's workshops – convincing evidence of the Company's productive capacity.

The picture shows the broad flange beam mill recently put into operation at a German iron and steel works. This mill is also used to manufacture new "European-type straight flange beams" (IPE sections).

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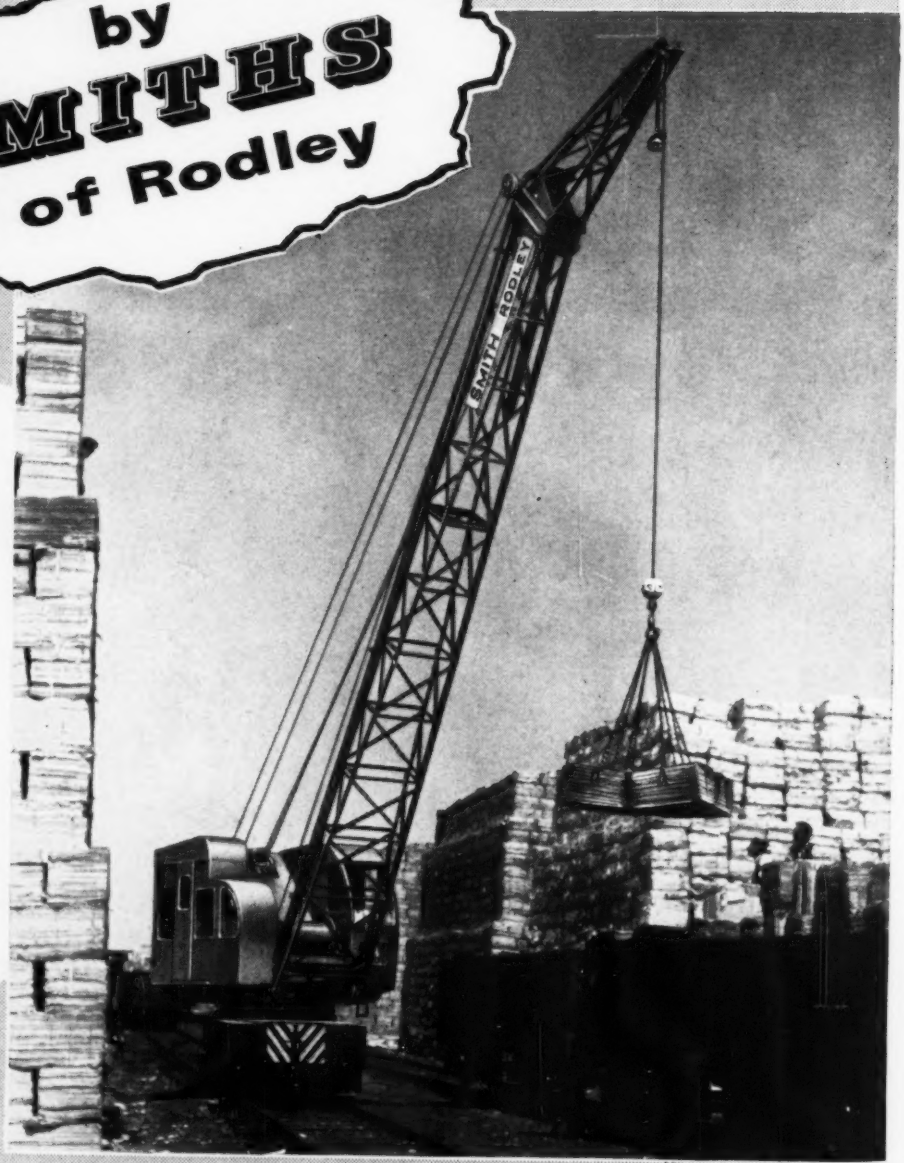
by SMITHS of Rodley



Smith Diesel and Diesel-Electric locomotive and shunting cranes serve many industries, particularly engineering and steelworks, docks and railways, stockyards, etc. Photograph at right shows a Smith 3-ton Diesel shunting crane engaged on stacking duties at a large paper mill in Lincolnshire. Using a 50 ft. cranked jib, it lifts 3 tons at 22 ft. radius. The very fast hoisting speed (200 f.p.m.) is ideal for this class of work.

THOMAS SMITH & SONS (RODLEY) LTD

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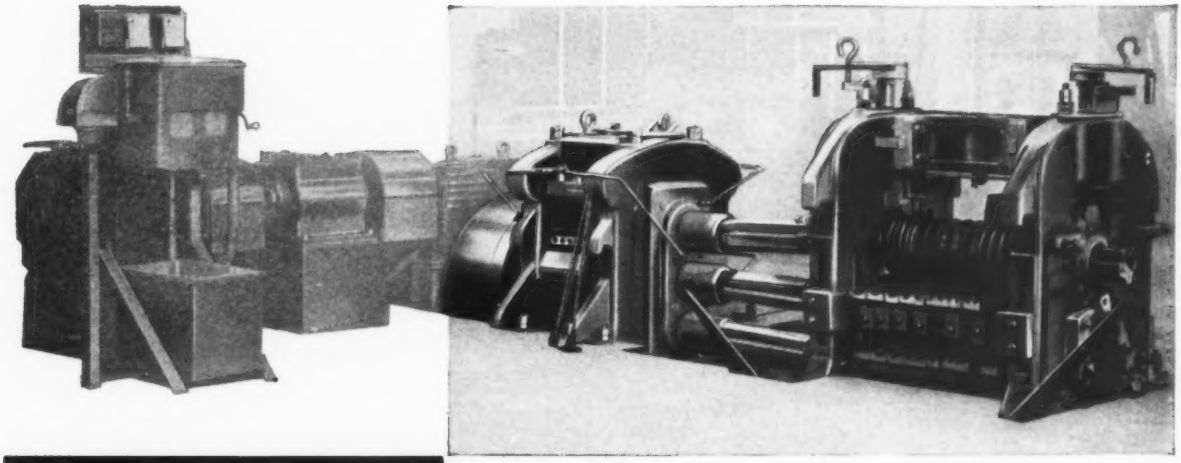

Thornton

12" Mill as supplied to Swinden Laboratories, Rotherham, and published by courtesy of The United Steel Companies Ltd.

Engineers and Contractors

Ingot Transfer Car for conveying 4/5 ton Ingots.

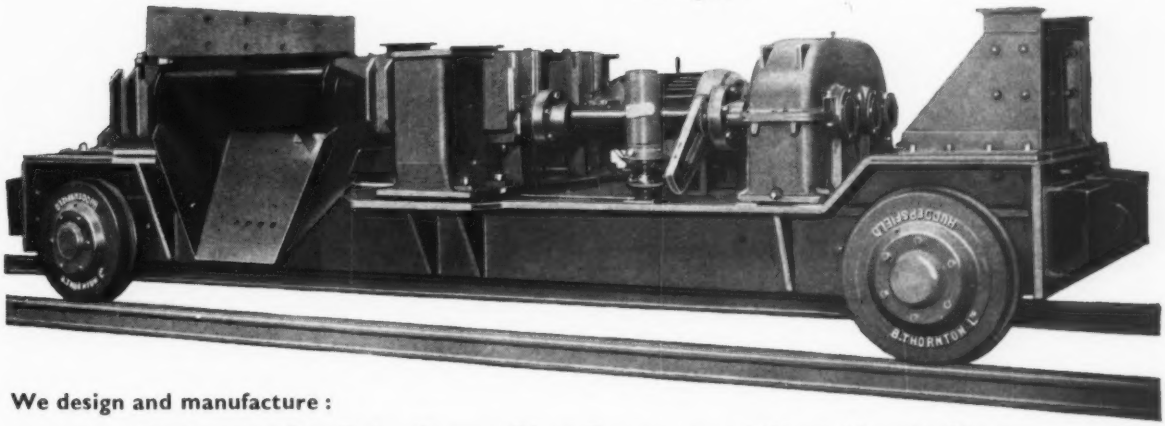

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Plate Work. Bogies of all kinds for carrying light or heavy loads.
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We shall be glad to quote against your requirements and specifications

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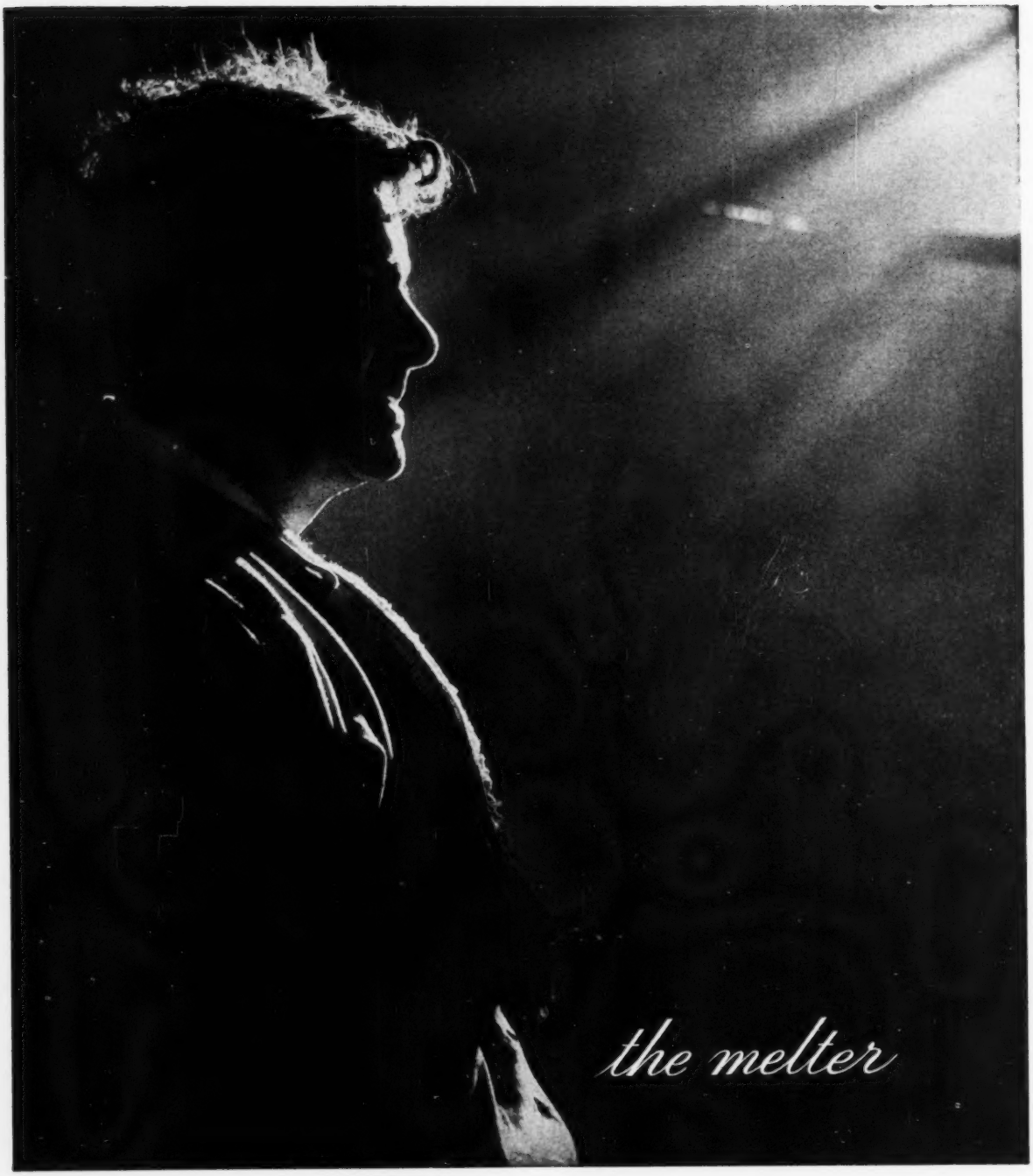

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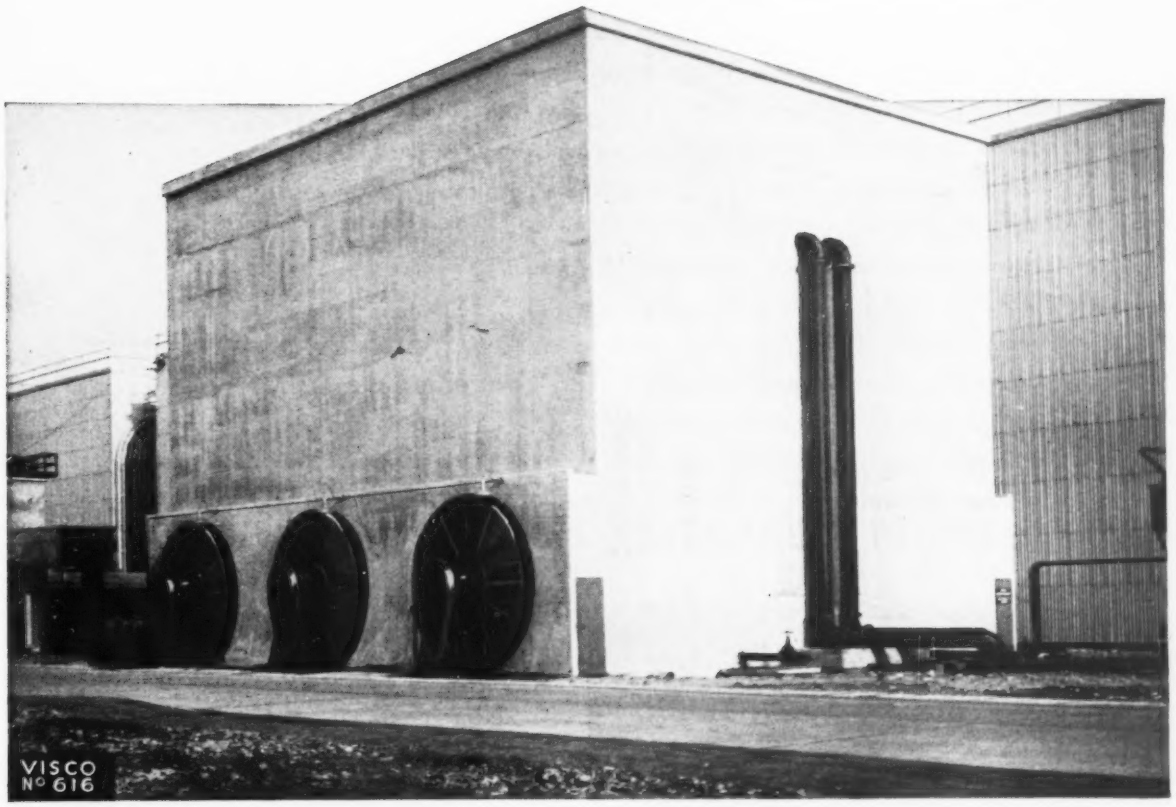

FWS

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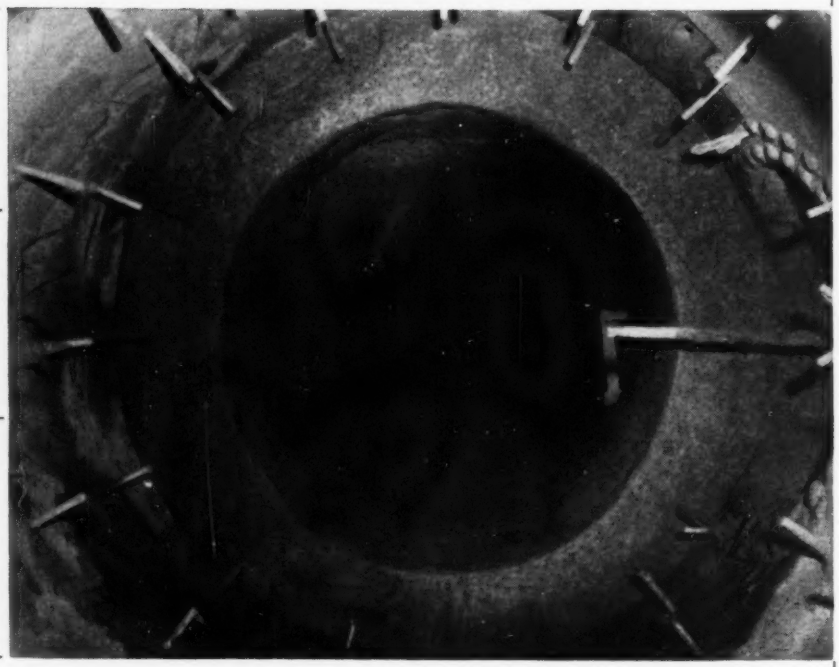
Data Sheet **No. 5**

THIS IS ---------- ? ----------

1 . . . AN EXTENSION TO THE LONDON UNDERGROUND

2 . . . THE BUSTLE MAIN OF A BLAST FURNACE

3 . . . THE INLET PIPE OF A HYDRO-ELECTRIC POWER STATION



Number two is the answer. It is in fact the bustle-main of the Queen Victoria blast furnace at Appleby-Frodingham in course of being lined with Tri-Mor 'Guncrete'. The main is 5 ft. in diameter and the 'Guncrete' lining 9″ thick. This is a far quicker and cheaper form of lining for a hot-gas main than brickwork. After twelve months continuous service this lining is still in perfect condition. Brick-lined mains usually require considerable repair after this period.

Tri-Mor 'Guncrete' is one of a series of new mouldable and castable refractories which are reducing first costs *and* maintenance costs in every kind of furnace from forging furnaces to ships' boilers. The most useful of these refractories are: - - - - - - - - - - ▸

TRI-MOR *Standard Castable*
TRI-MOR *High Strength Castable*
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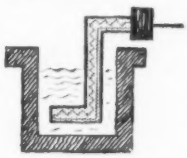
Resistance Heating – 2

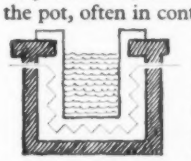
Electric resistance heating elements have been briefly described in Data Sheet No. 4, with two examples of their application in industry. This sheet lists some of the further applications which can be effectively dealt with by resistance heating.

Soft Metal Melting

Electric resistance melting is most commonly used for lead, tin, zinc, antimony, aluminium and their alloys—in processes such as tinning, type-casting, die-casting and lining bearings—at temperatures of up to around 800°C.



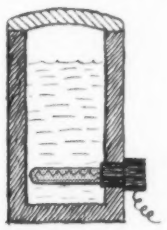
In most cases, sheathed elements are immersed directly in the metal, a more efficient method than applying heat to the outside of the containing vessel or pot. Immersion heating simplifies the application of lagging to the outside of the vessel, reducing heat losses and current consumption to a minimum. The elements are usually positioned near the inside wall of the vessel, leaving plenty of working space, but in a few cases, where the full volume of the pot is required, or where the metal to be melted is particularly corrosive, the elements are positioned outside the pot, often in contact with it.



In all cases, the precise temperature control that is so essential in soft metal processes is readily achieved by the use of electricity, and electric heating also leads to a reduction of casting rejects and metal wastage and a marked improvement in working conditions.

Liquid Heating

Electricity provides the ideal way of heating liquids such as water, oils, varnishes, plating, photographic and other solutions, and of melting and heating waxes and compounds, glues and pastes, tars and bitumen. Again, immersion heating is the method most commonly employed, but considerations of space or the nature of the liquid may sometimes necessitate the use of external heaters. Several types of devices are available to give precise and automatic temperature control, and lagging is again commonly applied to the vessel to minimise heat losses.

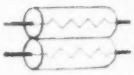


Fire hazards associated with inflammable liquids are invariably reduced by electric heating, particularly if immersion heaters can be used.

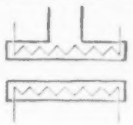
It is usually possible without difficulty to apply electric heaters, either immersion or external, to existing vessels.

Platen, Press and Roll Heating

Electricity offers the simplest and most convenient method of heating platens, dies and rolls. It gives the precise temperature-control characteristic of electric heating systems, with lower maintenance costs. Moreover, the relatively high temperatures required in some processes for maximum working speeds are reached without difficulty. Flexible electrical connections to moving parts give far less trouble than flexible pipe connections carrying hot water or steam.

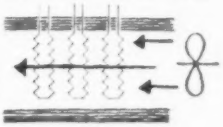


When electric heating is used, one or more presses can be operated without the necessity of keeping a boilerhouse staff at work.



Air Heating

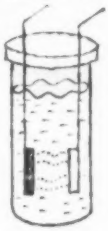
Streams of air, and of many other gases, can be heated most efficiently by electric resistance elements disposed across the duct leading to or from a fan. Heat is generated only inside the duct, just where it is required, and none is carried away through exhaust flues or pipes. Quick rise of temperature and precise temperature control are assured when electric resistance air heaters are used.



Electric Steam Boilers and Steam Raising

When steam is essential to a process, electrical steam raising can often be fully justified on economic grounds.

The means employed for bringing steam from a boilerhouse to the point of usage are often extremely wasteful, but where electricity is used the steam can be generated on the spot and losses from steam mains are eliminated. The efficiency of the electric boiler normally exceeds 96% and is practically constant at all loads, while the rapidity with which steam can be raised very largely eliminates banking losses.



Plant requiring process steam can be equipped with its own electric steam boiler, freeing the working space of steam mains just as individual electric motor drives free the factory of masses of shafting and belt drives.

Even where boilerhouse steam is still used, it is sometimes desirable for best results to boost the steam temperatures at the point of usage, to make up for transmission heat losses or to increase the superheat, and this function can most conveniently be performed by an electric resistance heater inserted in the steam line.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available – "Resistance Heating" is an example; "Induction and Dielectric Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

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HEAVY PLANT DIVISION RUGBY & MANCHESTER, ENGLAND

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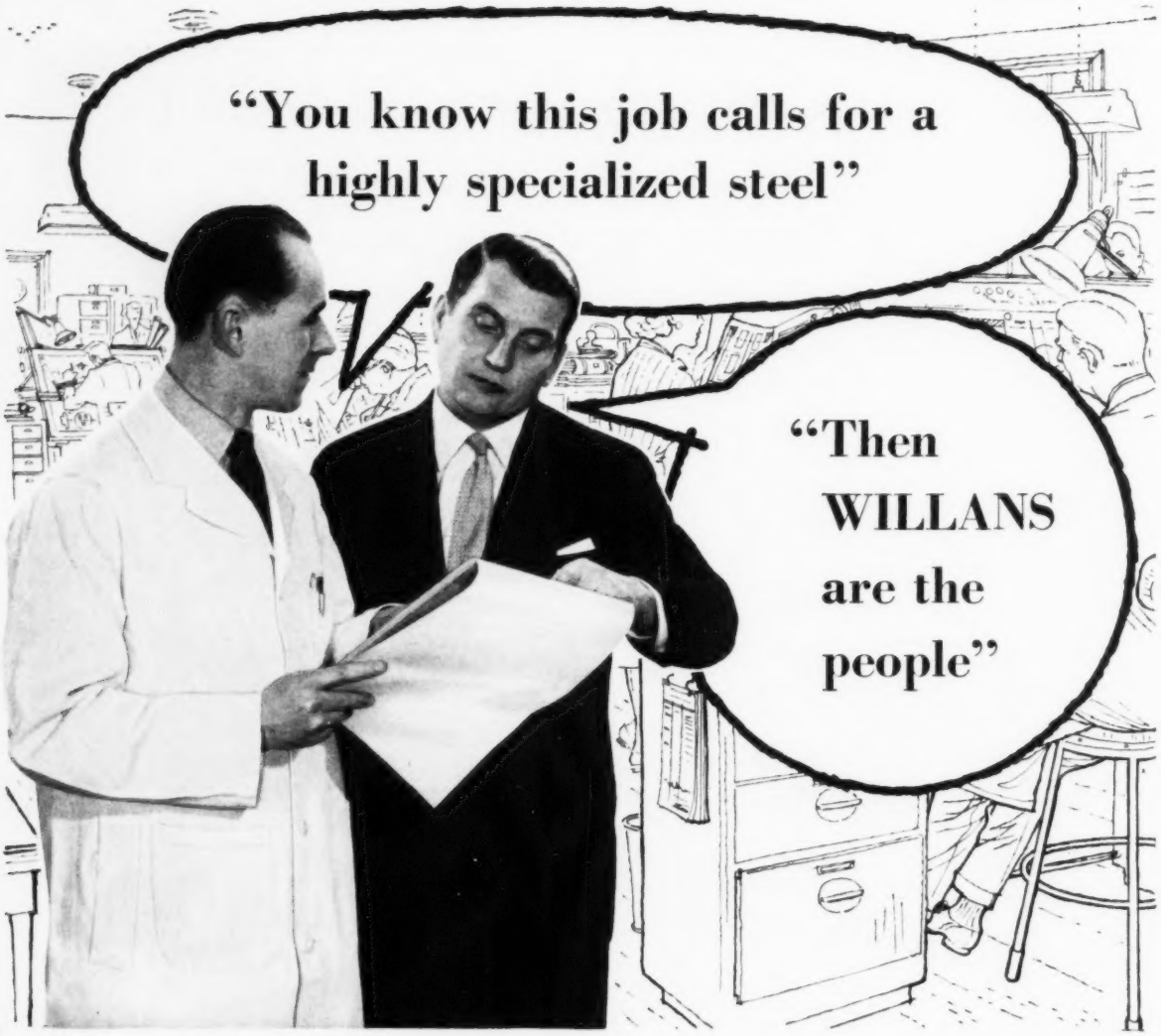

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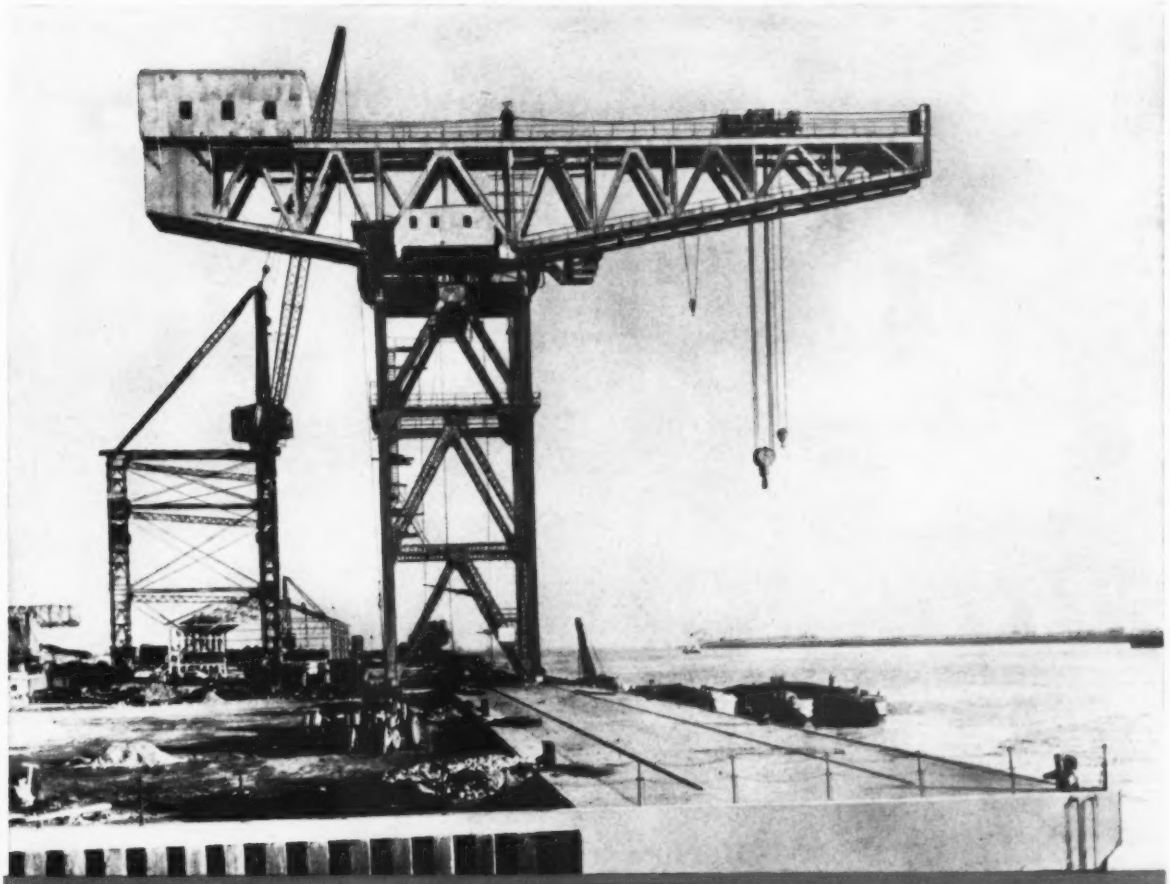

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An ever-recurring sight, throughout the world, to those who go down to the sea in ships—a harbour crane by Arrol of Glasgow. This new crane at Belfast N. Ireland has a main hoist with a capacity of 200 tons. Auxiliary and whip hoists deal with loads up to 25 tons and 5 tons respectively. The 220 ft. long cantilever supported by a tower 40 ft square can be rotated through a complete revolution in 10 minutes when carrying a full load of 200 tons.

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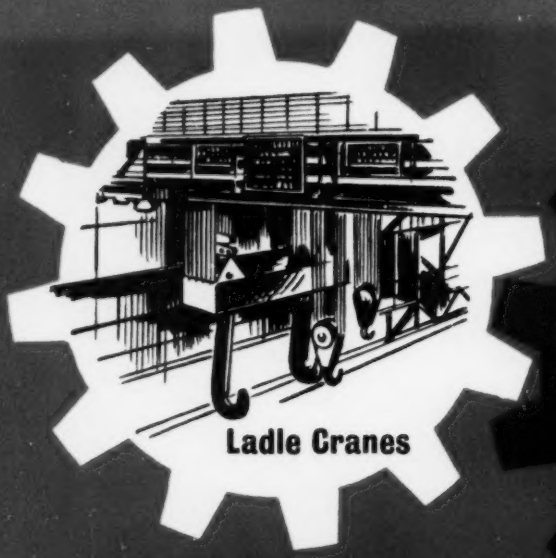

Ladle Cranes

Stripping Cranes

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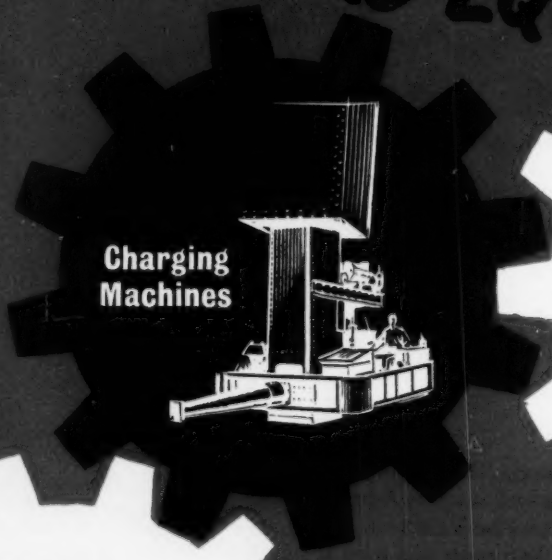
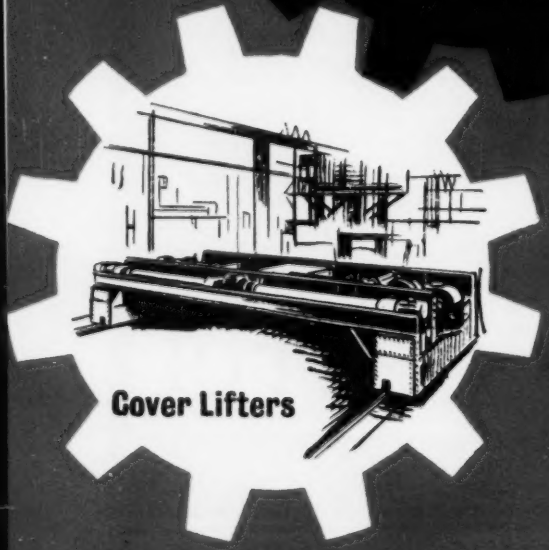


Charging Machines

Soaking Pit Cranes



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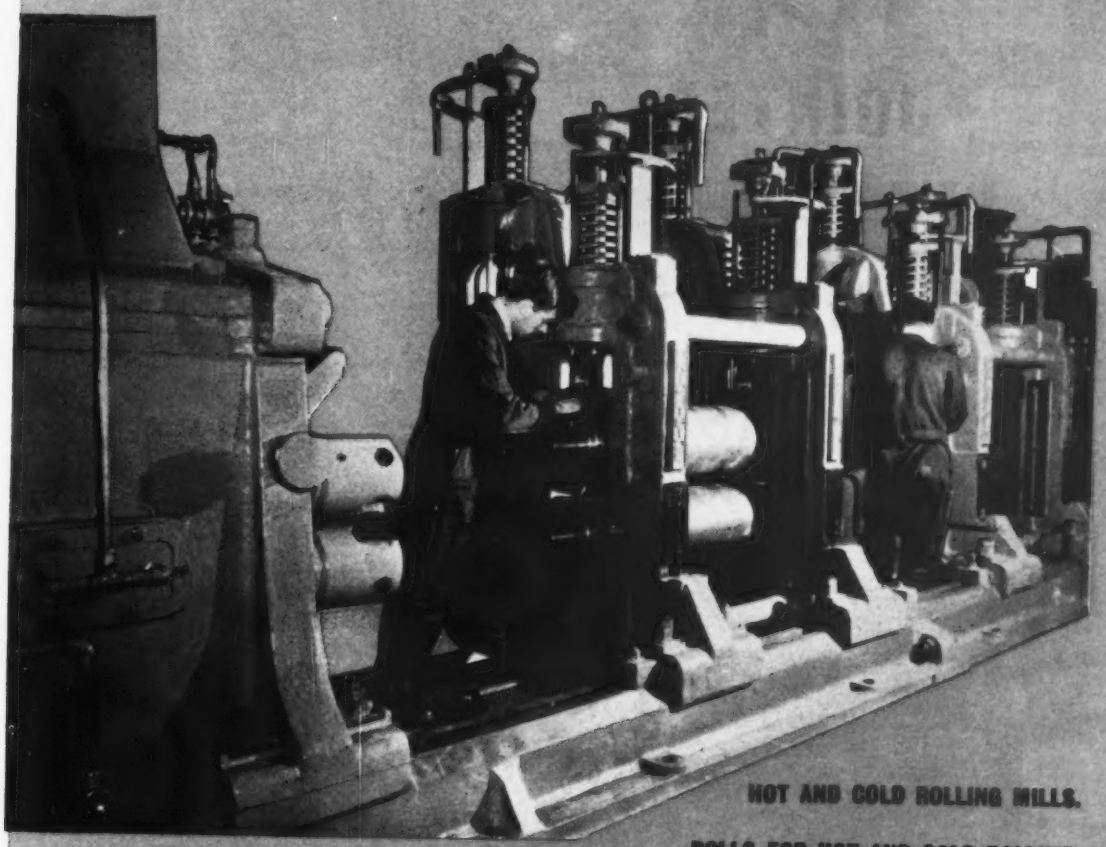

Shop erection photograph of a 10½" dia. Double Duo Rolling Mill for the precision rolling of Alloy and Tool Steel Bars and Rods.

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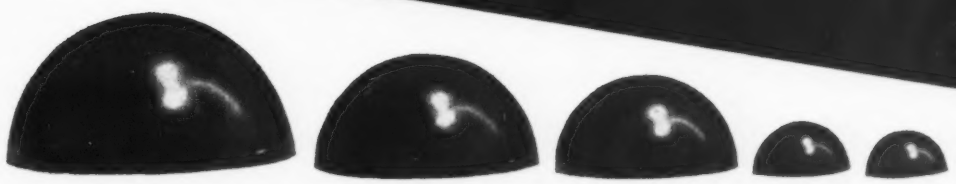

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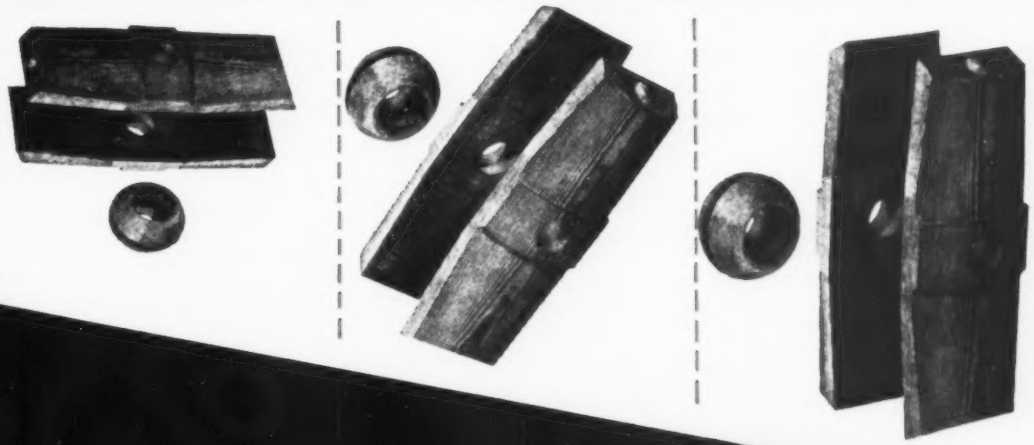

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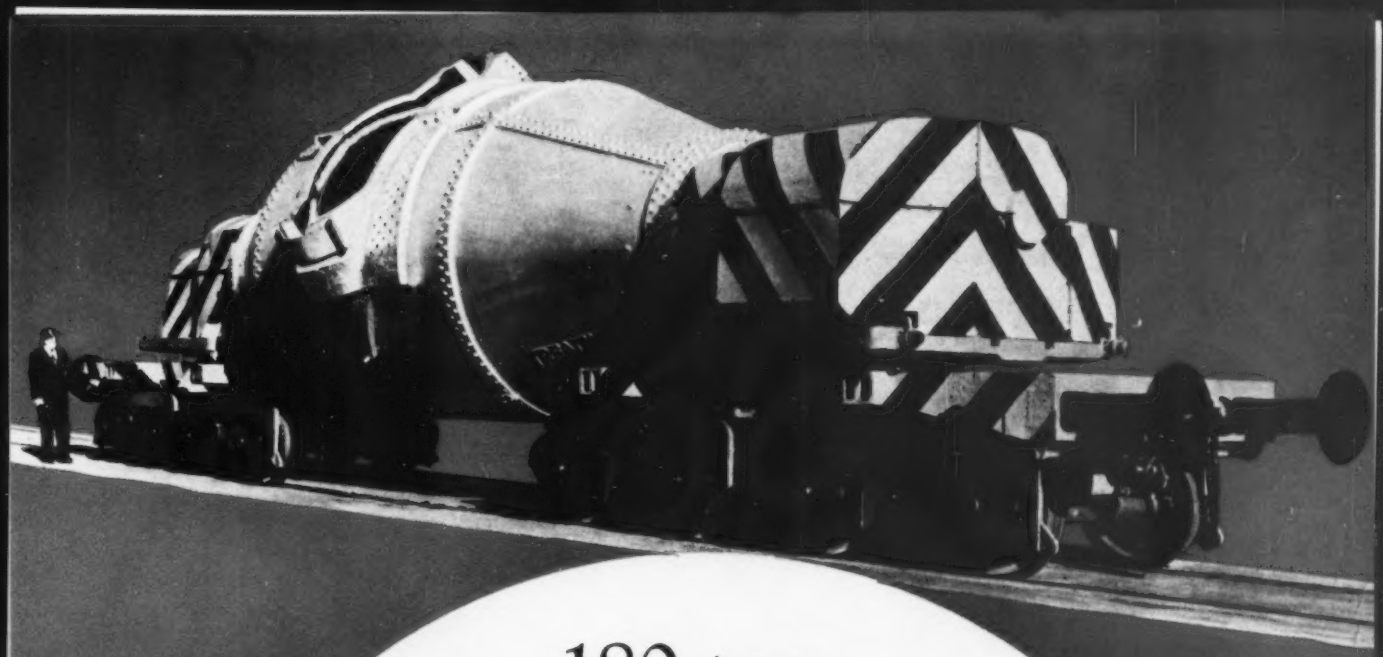

180 ton hot-metal ladle car

This hot-metal ladle car has been manufactured by Head Wrightson Teesdale Limited, under licence from the International Construction Company, London, for use by The Steel Company of Wales Ltd., and is by far the largest of its kind in this country.

As will be seen from the illustrations, the load is carried by four 4-wheel bogies and all the axles run in Timken tapered-roller-bearing axleboxes.

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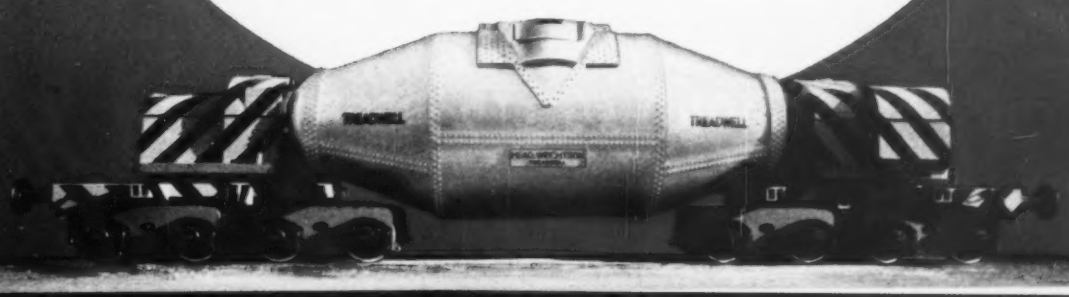

ROBERTSON

STRIP & SHEET PRODUCTION

Illustration shows a 15″ and 37″ x 60″ Reversing Four-high Cold Rolling Mill for soft, and alloy steel strip up to 50″ wide. Maximum rolling speed 1,200ft./min.

Photograph by courtesy of Messrs. Richard Thomas & Baldwins Ltd.

EQUIPMENT

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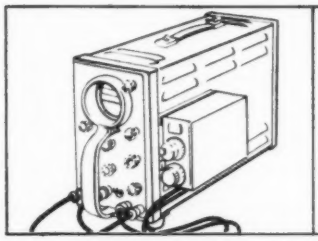
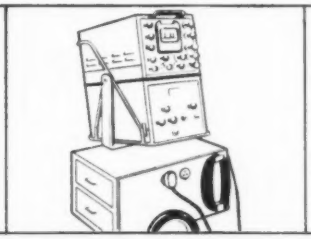
ULTRASONIC FLAW DETECTOR Mk. 6

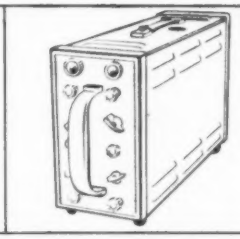
This powerful, versatile instrument has an exceptionally wide operating frequency range, and a variety of controls enabling particular methods of tests to be devised. The trolley mounted display and control units are readily adjustable to the most convenient position. A brilliant trace is given over the full width of a 6 in. C.R.T. Operates with single, twin or separate probes for contact, gap or immersion scanning. Automatic flaw alarm circuits, depth gauge and photographic recording facilities can be added.



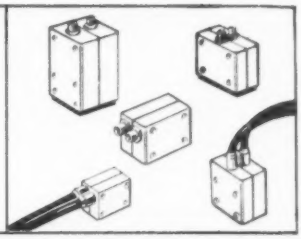
Flaw Detectors Marks 5F, 5AF. *Portable instruments with similar basic specifications. The 5F is a multi-frequency instrument for use with twin or separate type probes, whilst the 5AF, a single frequency instrument, either 1¼, 2¼ or 5 Mc/s. Also operates with single type probes. (Shown with Depth Gauge attachment).*



Flaw Detector Mark 6. *Trolley mounted transportable equipment, very powerful and versatile for use with all types of probes and having an exceptionally wide frequency range and high sensitivity.*



Two Channel Flaw Alarm. *For use with Mark 5 instruments, a portable auxiliary unit providing semi-automatic monitoring facilities which identify and give warning of significant defects.*



Probes. *Extensive development by Kelvin Hughes has resulted in a range of standard probes having either single, twin or separate transducers, and a very high performance throughout.*

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Includes a Depth Gauge for use with all instruments and which will measure thicknesses between 0.1 to 4 ins. with an accuracy of 0.75%. Probe Holders with irrigation facilities for large surface scanning, and remote Probe Manipulators.

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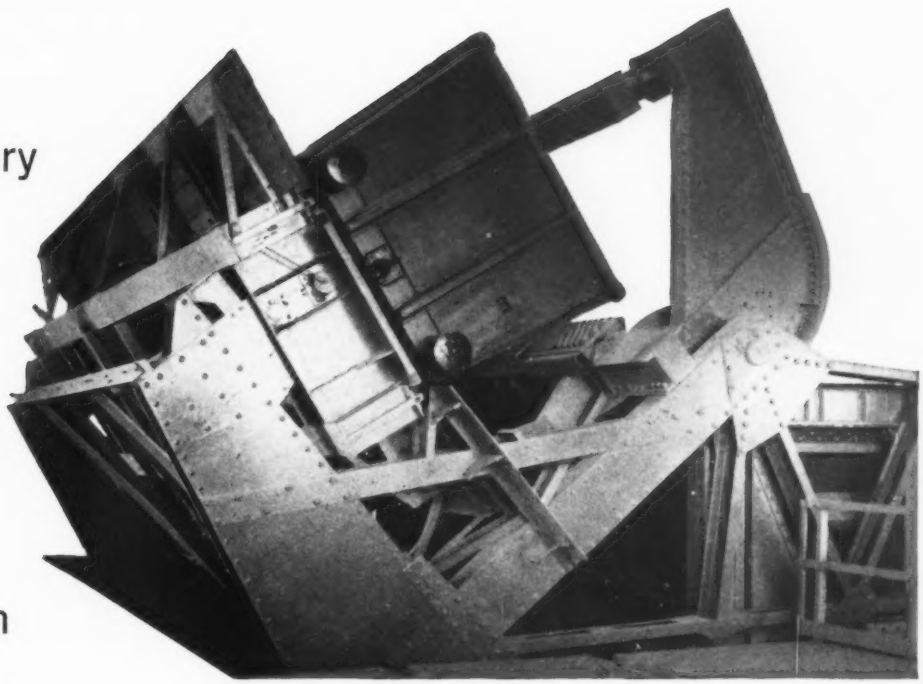
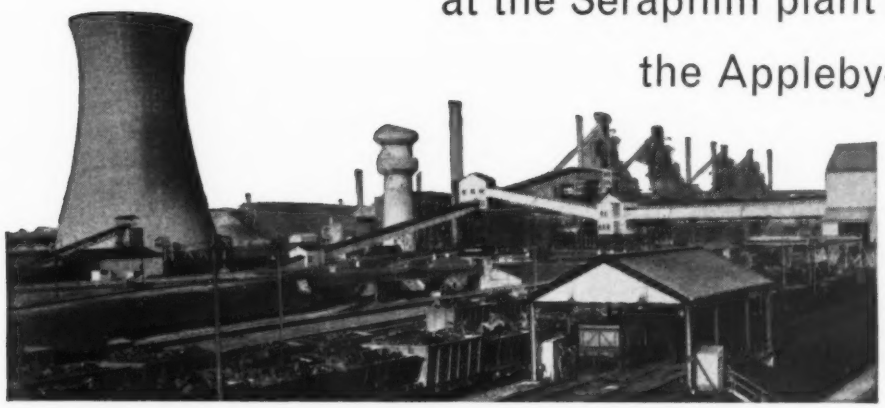


Branch of the United Steel Companies Limited.



This complete ore-handling plant was commissioned in 1954 and is typical of many materials handling systems which have been installed all over the world.

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Fraser & Chalmers Engineering Works · Erith · Kent · England

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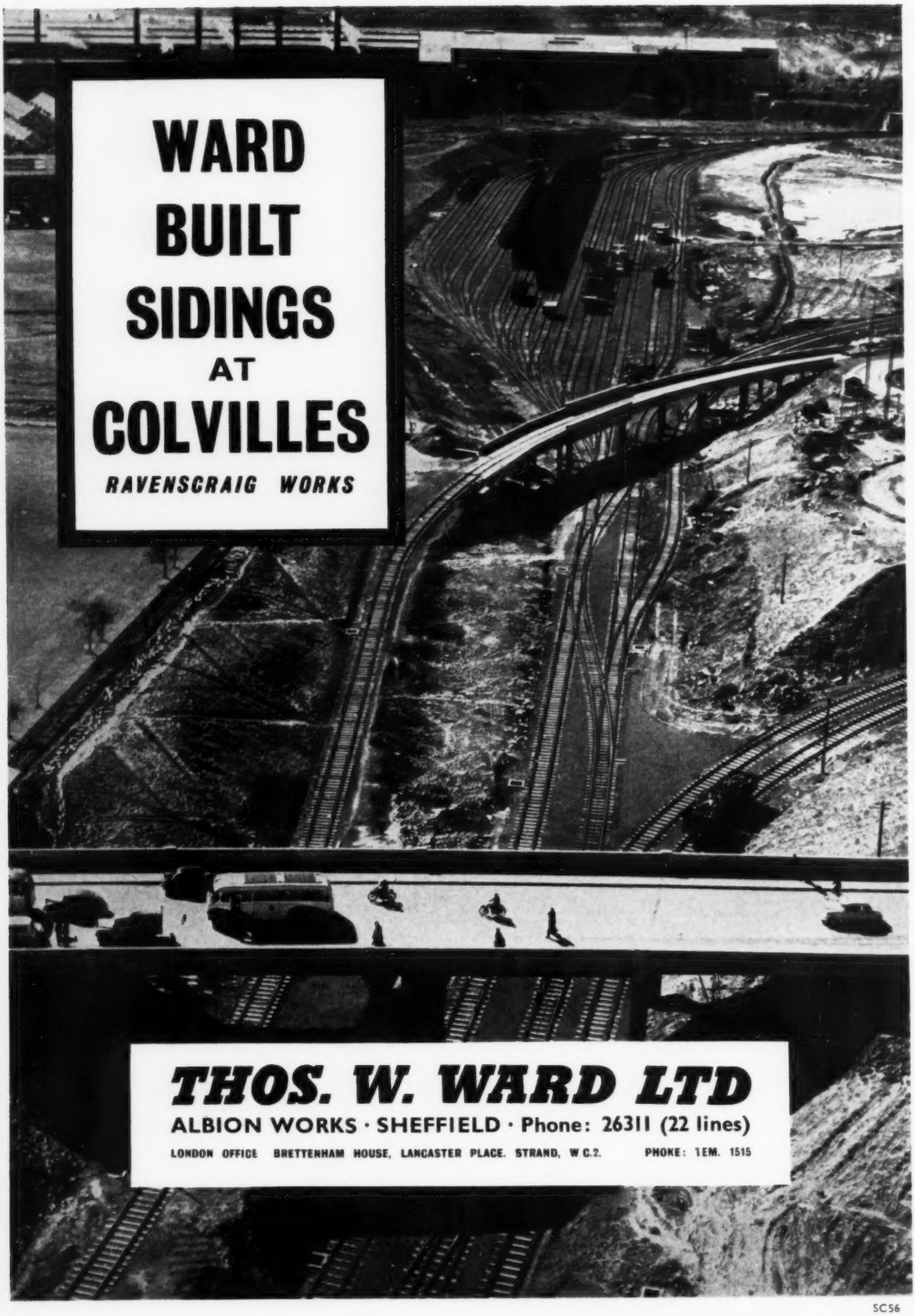
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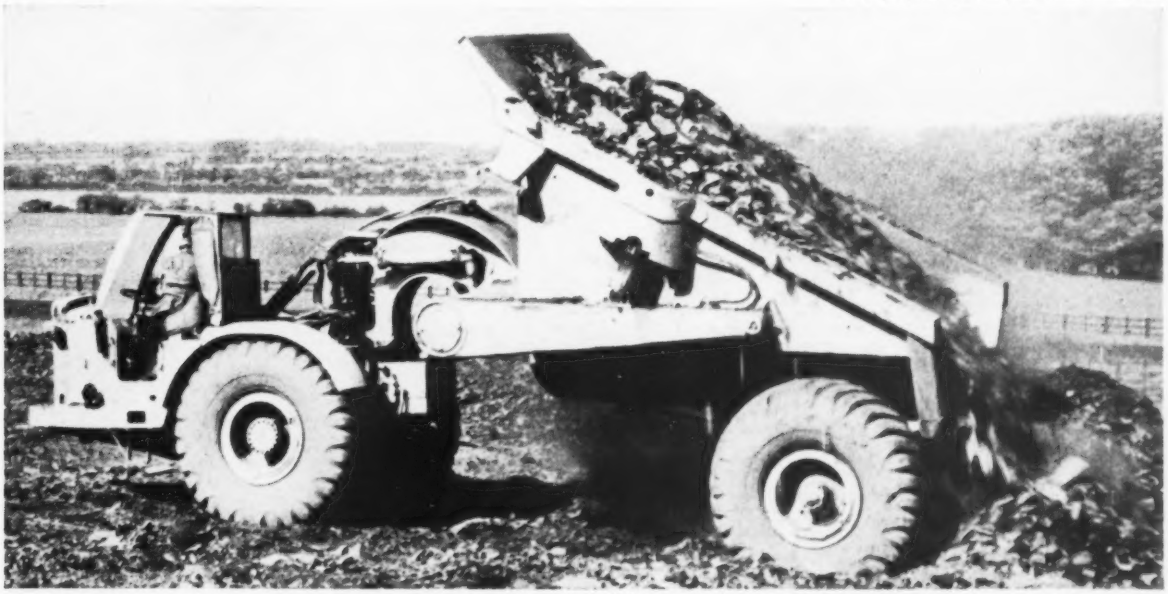
Today, five years later, the range of application for SCW Cor-Ten continues to grow as more designers and more users discover new ways in which they can take advantage of its outstanding properties.

Photograph by courtesy of Caterpillar Tractor Company Ltd.



Wherever higher strength or greater resistance to atmospheric corrosion offer economic advantages, SCW Cor-Ten *has been used. Where corrosion and abrasion are both present (as in the case above)* SCW Cor-Ten's *outstanding advantages are particularly effective.*

COR-TEN IS TOUGHER

- Weight for weight, the yield strength of SCW Cor-Ten is 50% higher than ordinary mild steel
  alternatively
  Strength for strength, a saving of $\frac{1}{3}$ of the weight is possible
- 4-6 times more resistant to atmospheric corrosion
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COR-TEN SAVES MONEY

- Initial costs are spread over a longer service life
- Maintenance costs are reduced
- Operating costs are lowered—in transport applications payloads are bigger because of reduction in tare weight

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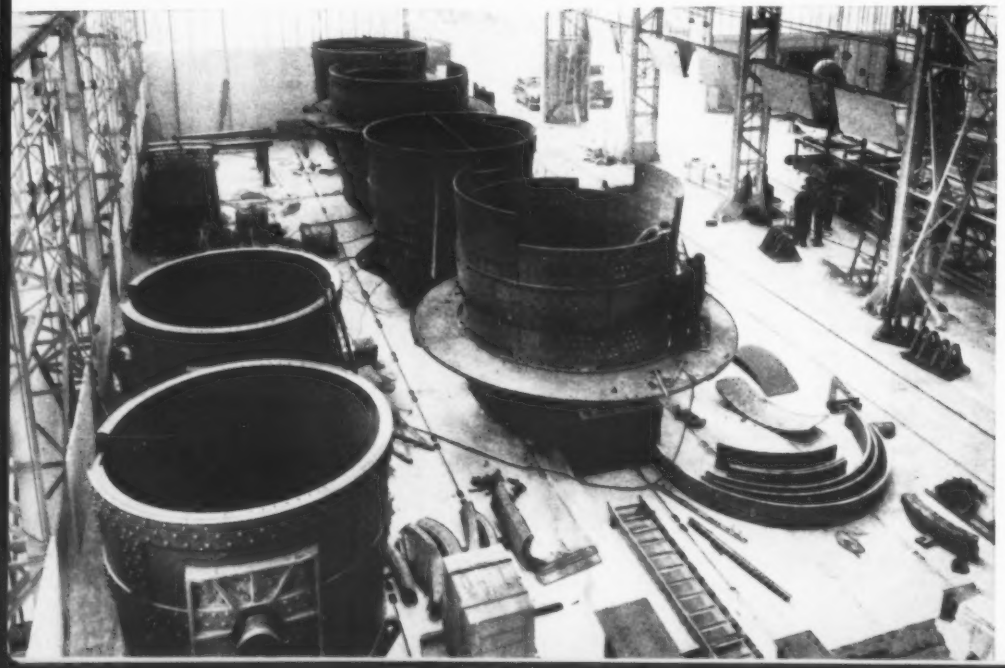
We bring to the service of the steel industry years of specialised design and manufacture of steelworks plant and equipment and we are to-day one of the largest suppliers of steelworkers ancillary plant, including ladles up to 300-tons capacity.

BELOW *275 ton ladles under construction at Thorncliffe.*



RIGHT *One of many steel casting ladles supplied to John Summers and Sons Limited.*

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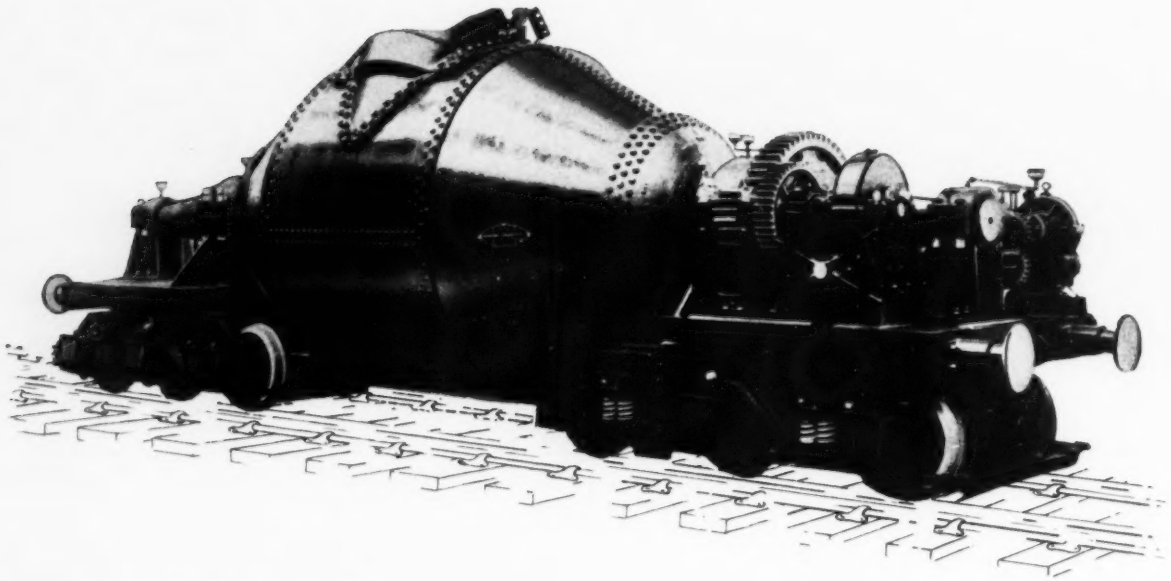

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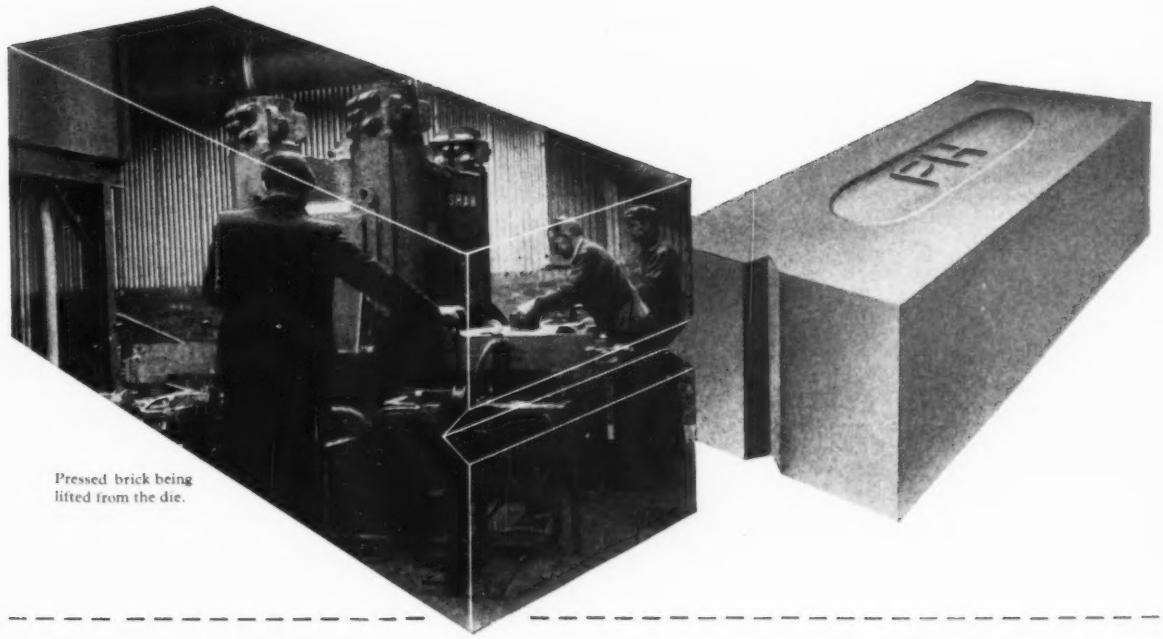

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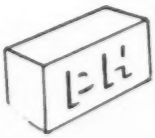

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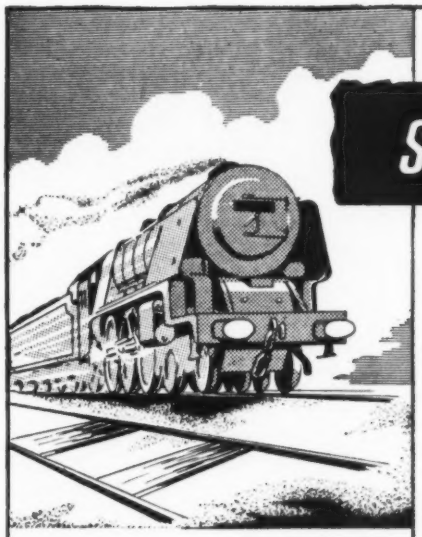

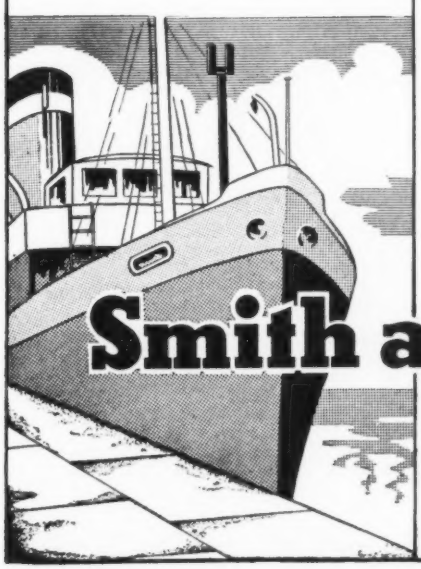

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Journal of The Iron and Steel Institute

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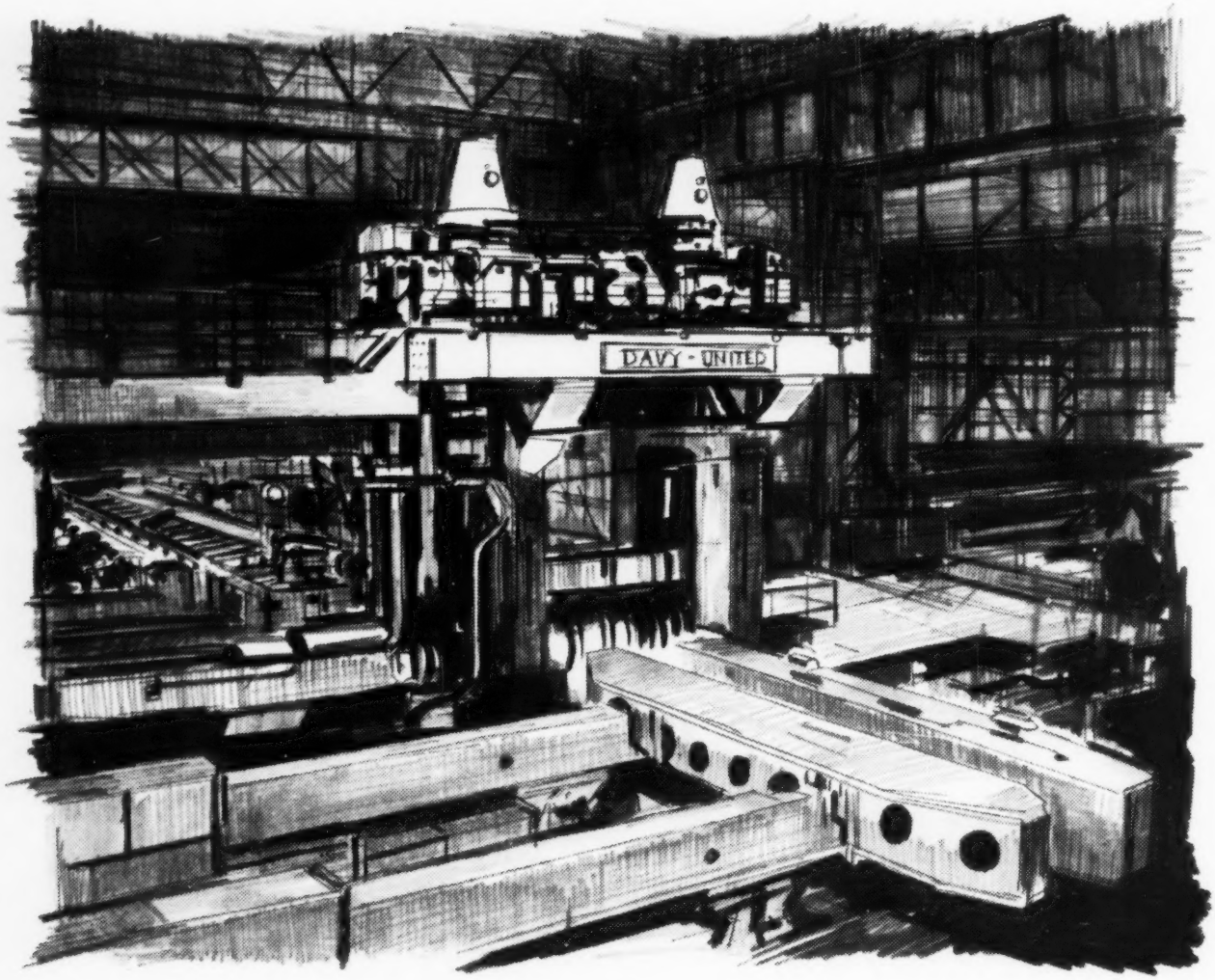

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W. BARR, O.B.E., A.R.C.S.T., F.I.M.

WILLIAM BARR was born at Larkhall, Lanarkshire. He was educated at the Hamilton Academy and the Royal College of Science and Technology, Glasgow, where he gained the diploma in metallurgy in 1921, and the associateship of the college in the following year.

In the First World War, Mr Barr served in the Special Brigade, Royal Engineers, and was mentioned in despatches. After completing his academic training he joined the staff of Messrs David Colville and Sons Ltd in 1922 as a metallurgist. In 1936, after the formation of Colvilles Ltd, he became chief metallurgist of the company, and was appointed a special director in 1947 and a director in 1954. He was appointed a director of the Fulwood Foundry in 1945 and chairman in 1957. In the same year he was awarded the O.B.E.

During his long association with Colvilles, Mr Barr has contributed articles and technical papers to numerous societies, his activities being specially devoted to researches on creep, brittle fracture of mild steel, and the development of low-alloy high-tensile structural steels and stainless-clad steels. In the Second World War he was a pioneer in the development and production of armour and bullet-proof plates by the basic open-hearth process. He was a member of the British Mission which visited the USA in 1943 in connection with the conservation of alloys in steel production.

Mr Barr's specialized knowledge of alloy steels and welding has been recognized by his service on many technical committees. Among those on which he is currently serving are the Research Board of BWRA, the Heavy Steel Makers' Technical Committee, the BISRA Metallurgy Panel, and the Technical Committee of Lloyd's Register of Shipping.

Mr Barr is a Founder Fellow and Past President of the Institution of Metallurgists, a Past President of the West of Scotland Iron and Steel Institute, and Chairman in Scotland of the Joint Committee for National Certificates in Metallurgy. He has been a member of The Iron and Steel Institute since 1925, a Member of Council since 1948, and Honorary Treasurer from 1953 to 1959, when he was succeeded by Sir Julian Pode. Mr Barr has been elected President of the Institute for 1959–1960.

W. Barr, O.B.E., A.R.C.S.T., F.I.M.

President, 1959-1960

PRESIDENTIAL ADDRESS

Progress in the development and application of steel plates

By W. Barr, O.B.E., A.R.T.C., F.I.M.

Throughout my career as a metallurgist, I have worked in close proximity to plate mills, and have thus been privileged to participate in some most interesting metallurgical developments in the field of industrial endeavour wherein plates are playing an ever more prominent part. It is my purpose here to review some of the factors that have influenced these developments and to indicate general trends.

My treatment of the subject is influenced to some extent by current events in our great industry, which, after many years of intense activity, now finds itself with capacity to spare. At such a time, the emphasis is on sales, especially for export, in the face of keen competition in a rapidly changing world. As occasion arises, I shall therefore refer to certain aspects of our steel specifications that fall short of the requirements of foreign customers who are no longer inclined to buy our steel because it is British, but who are influenced largely by the technical data made available by the salesman.

An obvious essential, which applies just as much to our existing standard steels as to the newly developed steels, is the availability of adequate technical data that are up-to-date, and here I think we have been at fault in the infrequent revision of our British Standard steel specifications. National standards of our main competitors, on the other hand, are in most cases revised at frequent intervals. Even though there is no substantial change made in the revision, the effect of the date of a specification on the mind of the buyer is obvious. In this respect, I am glad to note that over the last few years we have become much more active, as is evidenced by our lively participation on the various committees of the International Standards Organisation. The importance of this work cannot be too highly stressed.

In the past, when revising our steel specifications, our outlook, in my opinion, has been too insular, and when the revised drafts have been submitted to industry for comment and approval, we have been inclined to look at them against the background of our own mills and melting shops and price schedules. To maintain our position in overseas markets today, we must widen our horizon, and each specification should be critically examined in the light of specifications for comparable steels of other countries, so as to ensure that when our salesmen venture beyond our shores they have available all the necessary data to meet the requirements of the potential customer.

Another important and very relevant point that I propose to discuss refers to certain aspects of our engineering design codes which have a direct bearing on the data contained in some of our steel specifications for pressure vessels, a subject in which I am particularly interested.

Apart from developments relating to special steels, there is little doubt, at least among steelmakers, about the repercussions of modern fabrication techniques such as gas cutting and welding on the day-to-day production of even the more ordinary types of plates.

Gas cutting will often disclose minor laminations or clusters of slag inclusions which were often not visible on the sheared edge. More often than not,

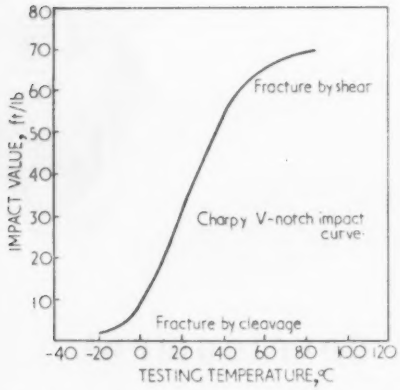

Fig. 1—Relationship between Charpy V-notch energy and temperature

such minor defects were of no practical significance with riveted construction, but their presence at the edge of a plate intended for welding may be a source of trouble, sometimes leading to the rejection of the plate, especially in the case of pressure vessels made to Class I standards subjected to X-ray examination.

In spite of statements sometimes made to the contrary, it is my opinion that the gradual introduction of the new fabricating techniques referred to has been matched by a gradual improvement in steel quality. In other words, plates produced in this country today are cleaner and more free from laminations than they were in the 'good old days'. In this connection, it should be borne in mind that the average thickness of plates in demand has simultaneously increased, and it is well known that defects of the type mentioned are more difficult to avoid in the heavier plates.

It is nevertheless appreciated that the fabricator is being called upon to meet standards of inspection that are increasing progressively. This, in turn, demands more stringent inspection of material at the steelworks. Apart from the examination of plate edges, preferably in the gas-cut state for plates over, say, $1\frac{1}{4}$ in. thick, the only available method for the routine assessment of the general internal soundness of the steel has been the examination of the fractures with the orthodox types of test-pieces – tensile, nick bends, etc. – and test-house managers are well aware of how closely these are scrutinized today. Within recent years, however, there has been introduced a new type of non-destructive test, by means of which the internal soundness of the metal can be more fully explored.

The ultrasonic test

The ultrasonic test, as its name implies, depends on the reflection of high-frequency or ultrasonic waves for the detection of hidden defects in a metal. It is particularly applicable to the detection of laminations in plates. Owing to the nature of the test, a very considerable background of experience is required to formulate standards for the various levels of quality to meet the requirements of different users. Indeed, so diverse are the applications to which steel is put, that at the present time it would be impracticable, if not impossible, to formulate universally applicable standards for the ultrasonic test. However, since this testing method is being applied by our foreign competitors, it is important that ultrasonic testing be accepted in principle by steel suppliers in this country. It is suggested that a realistic approach to this problem is to formulate only a basic standard which would establish the principle of ultrasonic testing and which would ensure the elimination of such internal defects as have proved troublesome to the average user in the past. The problem of supplying materials for special purposes such as atomic reactors, chemical plant, etc. can best be solved, in my opinion, by negotiation between the steel supplier and the other parties involved.

It is gratifying to note that the matter is being urgently pursued by our Heavy Steel Makers Technical Committee. Experience in the application of the test emphasizes the necessity for properly trained operators and experts with experience to interpret the results obtained. These factors had to be clearly recognized before the test could be regarded favourably for acceptance purposes.

Apart from the problem of acceptance tests as outlined above, there is every reason to believe that the installation of equipment for tests of this type at the rolling mills, suitably located and mechanized to minimize handling costs, will be a definite asset for quality control.

Notch ductile steels

Under this heading, British steelmakers can rightly claim to hold a leading position in the development of improved steels. As a preface to the discussion on the subject, it is as well to be reminded that the economy of the steel industry in this country, as in the USA, is based essentially on the bulk production of semi-killed or balanced basic open-hearth mild steel. This material, supplied to B.S.15 (28–33 tons tensile), or other similar specifications, has been used in the form of plates for ships' hulls, oil storage tanks, and a host of other structural purposes. As produced in this country, with a typical content of about 0·18% carbon and 0·5% manganese, such plates in the as-rolled condition satisfactorily met the tensile requirements with adequate ductility as assessed by the orthodox percentage elongation. For many years this material gave an excellent account of itself in service and was accepted without question for all types of structure. With the introduction of welding in place of riveting, however, certain alarming incidents occurred which undermined this confidence.

The much publicized incidence of brittle fracture in certain welded structures, including the catastrophic failure of a number of ships built in the USA under emergency wartime conditions, was the prelude to a vast amount of exploratory and research work on the mechanical properties of mild steel. The fact that there have been only three serious cases of brittle fracture in welded structures in this country, including one ship and two oil storage tanks, may be regarded as a tribute to British steel and workmanship. Nevertheless, we have been by no means complacent

in the matter, and some of our more notable contributions will be referred to later. In the world rush to investigate this problem, discoveries were claimed, which were merely confirmation of a long-established fact, that the percentage elongation in the tensile test is quite inadequate, in certain conditions of service, as a criterion of ductility. It was, of course, the recognition of this fact that led to the introduction, in the early years of the century, of the notched-bar impact test such as that devised by Izod in this country and Charpy in France. Unfortunately, the practical significance of the test had seldom been properly appreciated, and there was much confusion because of the scatter to which this test is peculiarly prone, a feature that was accentuated by the lack of proper standard testing methods.

In this country, metallurgists have long recognized the fundamental importance of temperature, state of stress (notch effect), and speed of deformation in assessing the notch ductility of steel, and these factors are being adequately covered in the revision of B.S.121 in which, for convenience in carrying out tests at various temperatures, the beam type of test piece with the V notch is favoured (the Charpy V-notch test).

In the familiar curve relating Charpy V-notch energy with temperature (Fig. 1), the transition from the ductile to the brittle condition usually occurs over a considerable temperature range, the actual extent of which depends on the composition and heat-treatment of the steel. Since the assessment of notch ductility is based essentially on the temperature of the transition, a problem arises owing to the difficulty of precisely defining this without carrying out sufficient tests to establish the shape of the curve, which is a tedious procedure. For convenience in acceptance testing, it is customary to specify a minimum energy value to be obtained at a certain temperature which may be related to the anticipated lowest temperature of service. For example, Lloyd's Register of Shipping in their revised rules for improved ship plates specify a minimum of 35 ft-lb at 0° C. It should be noted that this specification is based on an extensive survey of service failures in ships built in all parts of the world under conditions not always comparable with those in the UK.[1] There is, however, a wide body of opinion that 20 ft-lb at the lowest service temperature is adequate for most practical purposes.

In assessing notched-bar test results, various other related criteria may be used, notably fracture appearance, the transition temperature being taken as that corresponding with, say, 50% cleavage in the fracture. Unfortunately, there is no quantitative correlation between the test results based on the two criteria as between different steels, and since cleavage fracture is the invariable characteristic of brittle service failures, there is a widely held opinion that fracture appearance is the more reliable criterion in assessing service behaviour.

Fracture appearance can, of course, be applied in the Charpy test, but because of the restricted size of the specimen, the fracture face of which is only 10 mm × 8 mm, and because most service failures occur in the absence of impact, several forms of notch tensile or notch slow-bend tests have been introduced, most of which have the merit of employing the full plate thickness. The best known examples of this type of test in this country are the notch tensile test, developed by Dr Tipper of Cambridge,[2] and the Van-der Veen test developed in Holland.[3]

The problem of assessing the notch ductility of steel has been recognized by the International Institute of Welding, a sub-commission of which, under my chairmanship, carried out a systematic comparison of the results of various types of tests including Charpy V notch (energy) and the Van der Veen test (fracture appearance). This work was carried out on both ordinary and improved types of ship plates representing current production in the UK, Sweden, Demark, Holland, and Belgium. During the course of these investigations there was a free exchange of plates and test results. Indeed the only obstacle to progress was imposed by the Customs on the import of test specimens; so far as the interchange of knowledge and experience was concerned, there were no barriers whatever, which in itself was an encouraging experience.

This international work led to the publishing of two important conclusions which helped to clarify a situation that was rapidly becoming confused with the introduction of so many new forms of notched-bar tests. These conclusions[4] are:

(1) In the general class or ' ordinary ' mild steels, and for many other types, all tests rate the steels in approximately the same order of merit. For the various improved structural steels, some methods of manufacture improve one property more than another, but such individual improvements seem to give added safety to structures. An improvement in all assessments is presumed to give a greater degree of safety.

(2) Identity of transition temperatures from one test to another or from a test to service should not be expected, as each test or structure subjects the steel to unique conditions; nevertheless, some correlation may be established.

Pending further experience in the use of the two main criteria mentioned, it is current practice in this country to base acceptance tests on energy values obtained in the Charpy V-notch test and to record, for information purposes only, the percentage cleavage in the fracture. Moreover, it is the Charpy V-notch test that has been used in this country in the development of improved steels, and in this connection it is gratifying to note that British steelmakers were the first to realize the urgent need for a standard series of steels within the tensile range as ordinarily used for structural purposes but having guaranteed levels of notch ductility.

Investigators in this country discovered the importance of manganese in improving the notch toughness of mild steel, and this had led to the adoption of a minimum manganese/carbon ratio as a first step in the ladder of improvement. In the ordinary type of ship plate, as produced in this country, the manganese/carbon ratio is about 3. By adjusting this ratio to a value of the order of 8, a substantial improvement in notch ductility is obtained, and it is important to observe that this adjustment can be

Fig. 2—s s *Tank Emperor*, hull partly constructed of steel N.D. IV (20 ft-lb/min Charpy V notch at −50° C)

made without any major upset in the economy of production, since the steel of the balanced type can still be made. At the same time, it was appreciated that there would be a demand for still further improvements in the notch ductility for the more vulnerable parts of welded structures. For this purpose, a killed steel, grain-controlled and normalized, is best. Acting along these lines, the plate makers of this country, through the Heavy Steel Makers Technical Committee, collaborated in formulating the N.D. series of British Standard Notch Ductile Structura Steels (B.S.2762 : 1956). The progressive increase in the notch toughness of the N.D. steels from N.D.I. to N.D.IV is denoted by the specified Charpy V-notch values as follows:

N.D.I	20 ft-lb/min Charpy V notch	at		0° C
II	,,	,,	,,	− 15° C
III	,,	,,	,,	− 30° C
IV	,,	,,	,,	− 50° C

An interesting episode in the brittle fracture story refers to the high-grade steel classified above as N.D.IV. A proprietary steel of this type was on the market in this country about 15 years ago. It was originally developed to meet chemical engineering requirements for service at sub-zero temperatures, and it was a firm of Swedish shipbuilders who had the foresight to appreciate its advantages for shipbuilding as a safeguard against brittle fracture. The steel was incorporated in the more vulnerable parts of the ship's hull, including the shear and stringer strakes amidships. The first ship in which this steel was used was the s s *Tank Emperor* launched in 1948 (Fig. 2).

The development of improved notch ductile steels of the types described has proved of great value, but it must be admitted that in the light of present knowledge it is not possible to formulate any simple principle whereby steel with just the right level of notch ductility for any specific application can be selected. Service behaviour must, of course, be the final criterion, but as often as not there are no data available from past experience which can be used as a guide. There have, therefore, been several attempts to design large-scale laboratory tests which will closely simulate service conditions. Pioneer work in this field has been carried out by Robertson at the Naval Construction Research Establishment, Rosyth,[5] and by Wells at the British Welding Research Association.[6] The special testing machines designed by these investigators have been copied by other research establishments in this country and abroad, and some very useful conclusions have been reached.

Robertson, in his classical studies of crack propagation, has pointed out that in conventional notched-bar tests the fracture is propagated through metal that has undergone considerable plastic deformation, whereas in actual service failure brittle fracture is preceded by little or no plastic deformation. Robertson devised a test in which a brittle crack is initiated by a standard blow delivered in the immediate vicinity of a severely cooled notch at one end of a test bar along which there is a temperature gradient and to which a transverse stress can be applied as illustrated in Fig. 3. The temperature along the test bar at which the crack first shows signs of arresting is observed and termed the 'arrest' temperature. A typical Robertson curve showing the relationship between stress and arrest temperature for a 1-in. thick plate of mild steel is shown in Fig. 4. From this curve it is evident that to maintain the propagation of a brittle crack, two conditions must be fulfilled:

(1) The stress must exceed a certain critical value
(2) The temperature must be below a certain critical value known as the Robertson arrest temperature.

It will be observed that below the Robertson arrest temperature, the critical stress is well below the yield stress of the steel, this being in agreement with the observed fact that in service, extensive brittle fractures have occurred at normal working stresses of the order of 5 tons/in^2.

An outstanding problem was to reproduce in the laboratory initiation, as distinct from propagation, of fractures at the low values of nominal stress which characterize so many service failures. Wells pointed out that in notched-bar tests in general, even with a very sharp notch and at a temperature well below the fracture transition temperature, the nominal stress in the test-piece had to attain or exceed the yield stress before fracture was initiated. Wells, following a lead by Greene,[7] investigated initiation phenomena by means of wide-plate tensile tests in which the test-piece has a longitudinal butt weld located at mid-width, and having a fine saw-cut notch introduced at the mid-length of the edges of the plate before welding. Wells' results confirmed Greene's observations that in this type of large-scale test, in which conditions approached those in actual welded structures, it is possible to initiate fractures at very low values of nominal stress. The explanation, as pointed out by Wells is that "Longitudinal weld shrinkage during cooling in the presence of the notch satisfied independently the condition of general

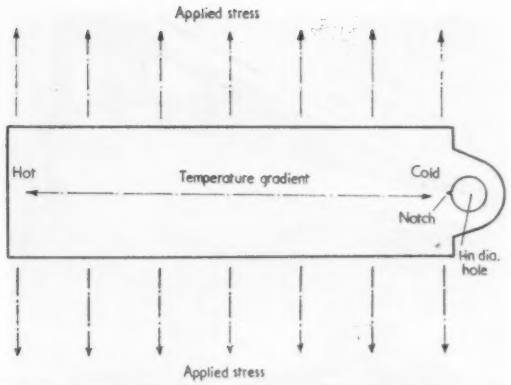

Fig. 3—Robertson test for determining conditions for arrest of a brittle crack propagating through undeformed metal

yield without external load." In other words, these tests indicated in a striking manner the influence of residual stresses due to welding in initiating brittle fracture at a local weld defect. This undeniably explains why catastrophic brittle failure came into prominence only when welding was generally introduced in place of riveting.

The preliminary results obtained by Wells confirmed that a low transition temperature, as shown in the Charpy V-notch test, provided an additional measure of safety to a welded structure.

A second valuable conclusion derived from early experiments with the Wells type of test was confirmation of the influence of stress-relieving treatments as a means of safeguarding a structure against initiation of brittle failure. Kennedy,[8] working in collaboration with the British Welding Research Association, was able to show that removal of the residual stresses provided a complete safeguard against the initiation of brittle fracture at low nominal stress. For a mild-steel structure, treatment at 650° C for 1 h was shown to be fully effective for the purpose, while the Linde method of local redistribution of residual stress provided a moderate degree of stress relief. Kennedy also showed that the same benefit was obtained where stress relieving was carried out by general yielding, thus proving that the benefits of the orthodox thermal stress-relieving treatment are due to elimination of the residual stresses and not to metallographic changes in the thermally disturbed zone of the weld, as had been suggested in some quarters.

The practical significance of residual welding stresses has, of course, been long recognized in certain codes of practice for construction of pressure vessels, which make stress-relieving mandatory. It is true to say that in such cases brittle fracture has never presented a major problem in this country.

Thus I have attempted briefly to present the salient features of the brittle fracture story, which has brought new problems alike to the man in the melting shop, the mills, and the metallurgical laboratory, and to the design engineer. Progress to date is evidenced by the large-scale production of steels to guaranteed levels of notch ductility, which is a regular feature of the output of many mills in this country today.

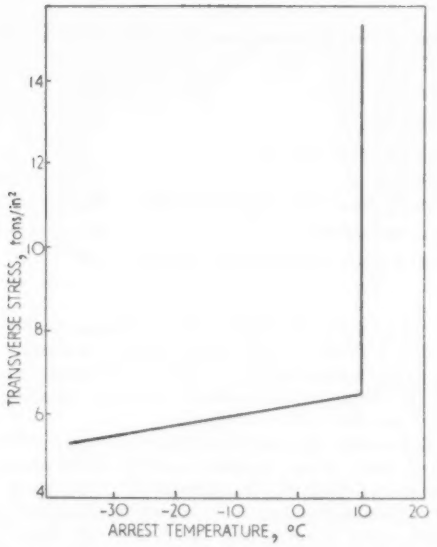

Fig. 4—Characteristic Robertson stress/arrest temperature graph

The application of plates in pressure vessels

Plates used in pressure vessels are made to a standard known as ' boiler quality,' because of their traditional use in the manufacture of steam boilers where, for reasons of safety, a higher and more uniform standard was required than for ship-quality plates. The quality of such plates is controlled by specifications which call for acceptance tests from each rolled plate.

At one time most of the boiler plates in this country were made from acid open-hearth steel, but over the last 20 years or so, owing to improved production techniques, the great proportion of the plates are made from basic open-hearth steel, which is capable of meeting all demands.

Here again the introduction of welding in the fabricating shops has had its effect in a gradual upgrading of steel quality to meet the stringent demands imposed by the inspecting authorities. Because of the practice of stress relieving, notch ductility is not a major problem, and no British specifications for plates for use in pressure vessels make reference to this factor except for service at sub-zero temperatures. In many Continental countries, where steels produced by processes other than the open-hearth process were permitted for pressure-vessel construction, specifications for pressure-vessel steels include a notch ductility clause for boiler-shell plates. For commercial reasons, therefore, this factor should be borne in mind when revising our relevant specifications, since it may have a considerable influence on our steel exports.

To the fabricator, welding as opposed to riveting has made it possible to meet demands for more economic power production by increasing operating pressures and temperatures. Progress in this direction has proceeded apace, with progressive increases in the thickness and dimensions of plates. This, in turn, has led to a demand for higher-tensile steels.

TABLE I

Comparison of specifications for large welded drums

	1935	1958
Length, ft	35	66
Diameter, in.	54	60
Plate thickness at weld, in.	1¼	5
Weight, tons	16½	112
Working pressure, lb/in² (safety-valve load)	390	2 750
Test pressure, lb/in²	780	4 125
Minimum tensile strength of plate, tons/in²	28	38

The trend in this development, according to Harris[9] (Table I), is illustrated by a comparison between what was a large welded drum in 1935 and drums (Fig. 5) currently being manufactured in this country for some of our new power stations.

In discussing the subject Harris states "When it is noted that drums similar to that listed above as indicative of 1958 are manufactured with much less difficulty and a freedom from repair welding unknown in 1935, some idea of the improvements that have been quietly taking place in the science of welding can be gained." These observations may also be claimed as a tribute to the improvements in the steel which have been proceeding just as quietly in close collaboration with our friends on the fabricating side.

The best quality of steel for welded pressure vessels is silicon-killed cast in wide-end-up ingot moulds with hot tops. For plates of reasonable dimensions at 5 in. thick, an individual plate may weigh as much as 20 tons, being rolled from a 35-ton ingot. That is to say, the ingot-to-plate yield is only 60%. However, even with this practice, a major problem arises from the variation in chemical composition, and particularly the variation in the carbon content from the bottom to the top of such large ingots; the higher the carbon content of the steel, the greater the problem in this respect. For this reason there is a limit to the tensile strength that can be achieved in such heavy plates in a straight carbon–manganese steel without risk of welding troubles due to local concentrations of carbon at the central axis of the plate adjacent to the top discard.

Such difficulties can be minimized by the use of a low-alloy steel with a low carbon content, so that the segregation of this element is reduced.

In theory there are many ways in which one can ring the changes in the choice of alloys for steels of this type, but in practice the final choice must inevitably be influenced by costs so that the product may be economically attractive to the user.

The problem has been tackled in various ways, and there have been several interesting developments, but I propose in the time available to confine my remarks to one particular steel, in the development and application of which I have first-hand knowledge, and which, like other steels of this type, is characterized by a relatively high ratio of yield stress to ultimate tensile strength. My object here is to illustrate from a practical example how certain aspects of our design code prevent the application of these steels in as economic a manner as is possible in certain Continental countries. This refers particularly to the use of the steels in the medium temperature range as in steam boiler drums.

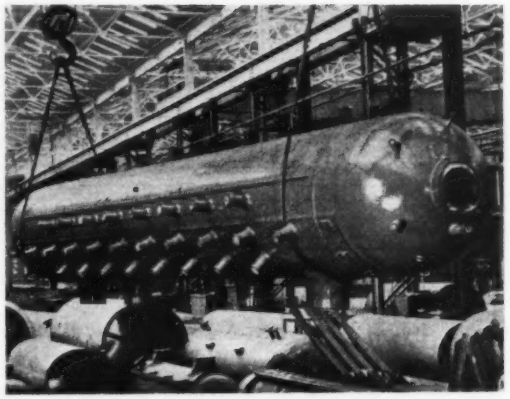

Fig. 5—Modern high-pressure steam drum

This proprietary steel, which contains a particular combination of manganese, chromium, molybdenum, and vanadium, is being produced regularly in large tonnages in the form of plates up to 5½ in. thick and is giving satisfactory service in some of the largest welded steam drums in modern high-pressure power stations in this country. The guaranteed minimum tensile for plates within the thickness range 3–6 in. is 36 tons/in², which is the relevant factor for design purposes according to current British practice. Details of the development of the steel and its behaviour in fabrication have been discussed elsewhere.[10] The salient features of the steel are given in Tables II–IV.

The design stresses employed in this country for both ordinary carbon steels and special steels of the type mentioned above are substantially lower than the stresses used for similar steels in many other countries. Apart from the effect on the cost of construction of vessels for use in this country, the situation is having adverse repercussions on our exports. The extent of our handicap in this respect is shown by the difference in design stresses permitted for the above steel according to British and Continental codes of practice. For a service temperature of 350° C (660° F), the British Standard B.S.1500 stipu-

TABLE II

Manganese–chromium–molybdenum–vanadium steel

Chemical analysis	Specification, % max.	Target, %
Carbon	0·17	0·15
Silicon	0·30	0·15
Sulphur	0·05	...
Phosphorus	0·05	...
Manganese	1·50	1·3
Chromium	0·70	0·50
Molybdenum	0·28	0·26
Vanadium	0·10	0·08

TABLE III

Specified temperature proof stress data

Thickness	0·2% proof stress, tons in² minimum								
	20 °C	100 °C	200 °C	250 °C	300 °C	350 °C	400 °C	425 °C	450 °C
Up to 1 in.	30	29	27	26	25	24	23	21	19
Above 1 in. up to 3 in.	27	26	25	24	23	22	21	19	17
Above 3 in. up to 6 in.	24	23	22	21	20	19	18	17	15

lates that the design stress shall be one-quarter of the ultimate tensile strength at ambient temperature. The Continental code, on the other hand, stipulates that the design stress shall be two-thirds of the 0·2% proof stress at the service temperature, provided that this does not exceed 75% of the ultimate tensile strength. The design stress for this steel under these conditions is 8½ tons/in² following the British code, compared with 14 tons/in² following the Continental code. It will be appreciated that the acceptance of the proof stress instead of the ultimate tensile strength as a basis for design in the intermediate temperature range reacts most unfavourably in the case of the low-alloy steels of the type described. A comparison of the design stresses, British *v.* Continental practice, is illustrated in Fig. 6.

An example of what this means in practice may be quoted. On a recent occasion, this steel was used for the manufacture in this country of a welded vessel designed for a pressure of 2 060 lb/in² and an operating temperature of 340° C (644° F). The vessel was intended for export to a Continental country and design was based on the 0·2% proof stress at the operating temperature, the data for which were made available by the steelmaker (*see* Table IV). The result was a vessel, the shell plates of which were 2½ in. thick, but the same vessel used for the same purpose in this country would have required the thickness of the plates to have been increased to 3½ in.

After the vessel had been manufactured and despatched, the Continental authority, while accepting the basis of design, found itself in some difficulty because there existed no standard specification in

TABLE IV

Typical high-temperature tensile data
5-in. thick plate normalized from 900° C, tempered for 2 h at 650° C

Plate analysis, %	C	Si	S	P	Mn	Cr	Mo	V
	0·15	0·13	0·030	0·020	1·32	0·65	0·23	0·07

Testing temperature, °C	0·2% proof stress, tons/in²	UTS, tons/in²	Elongation %, $4\sqrt{A}$
20	29	38	26
200	25	35	24
300	22	36	25
350	24	38	22
400	20	34	23

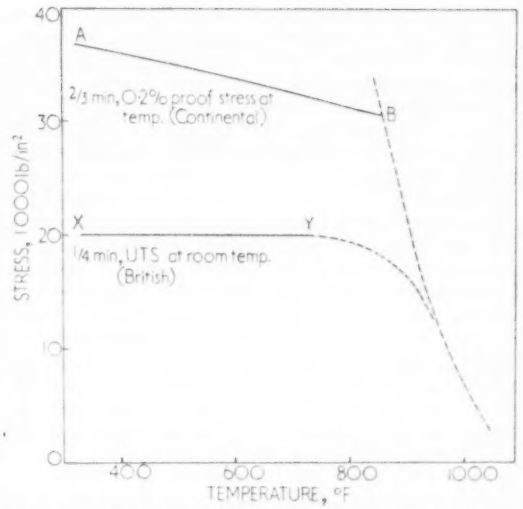

Fig. 6—Design stress (below creep range) for high-yield low-alloy steel, 36 tons/in² UTS

the country of origin of the material which imposed any control on the proof stress at the service temperature. Eventually it was agreed to treat the certification of the vessel as a 'special case,' and it was ultimately accepted following the satisfactory completion of additional proof-stress tests carried out under independent supervision.

The above case illustrates the difficulties that beset British manufacturers tendering for plant of this nature to the many countries which accept Continental practice. If British industry is to compete on anything like even terms with foreign manufacturers in world markets, it is evident that advantage must be taken, in suitable cases, of the superior intermediate temperature properties of low-alloy steels and British Standard Specifications making reference to 0·2% proof stress data for such steels are urgently required.

If we are to maintain our competitive position, it is desirable that we make the most effective use of carbon and alloy steels compatible with adequate safety. It is necessary to consider, therefore, the factors that limit the design stress adopted by a British firm producing vessels for both the home and export markets.

Considering first the position with regard to vessels produced for the home market, even if the fabricator is satisfied that he could safely increase the design stress above the figure recommended in the appropriate British Standard, he cannot do so without the approval of a competent inspecting authority. It is generally true to say that none of the British inspecting authorities is prepared to approve any design procedure which would involve the use of design stresses higher than those stated in the appropriate British Standard. As a consequence of this policy, an alteration in design procedure that would result in an increase in the stress on the steel can only be brought about by amendment of the appropriate British Standard Specification.

A British Standard Specification, at least in so far

as it concerns pressure vessels and boilers, etc., is the result of a compromise between the engineering insurance companies' views and the manufacturers' views. It is intended to be an indication of what is standard practice. Therefore, standards are not amended to cover improved procedure until use in service has shown that the procedure is satisfactory. Thus, it is usually the case that where service conditions demand a type of construction outside the range covered by an existing British Standard, agreement has to be obtained between the purchaser and the manufacturer on the features of design or methods of manufacture which are departures from standard practice. In the sections of engineering to which reference has just been made, it is fortunate that British manufacturers do considerable business abroad, where they are able to obtain evidence of the satisfactory performance of advanced designs and are able to use this evidence in arguing their case for modification to existing British Standards.

Engineering insurance companies in Britain are the people who decide the insurance premium to be paid on any new plant and, because of the vague wording of the Factories Act, 1937, their engineers are normally regarded as the persons competent under the Act to certify a pressure vessel for service under the conditions for which it was installed. There are very few legal regulations in the UK relating to the design of pressure equipment of the class under discussion, and so it has become customary for specifications such as B.S.1500 and B.S.1113 to be used as the criterion upon which the fulfilment of the Act is determined.

A consequence of the above procedure is that progress in development of design procedure for vessels is very slow. In the early part of the century, the procedure proved satisfactory in that technological progress was also slow and the standard design practice never fell too far behind the most advanced practice employed elsewhere in the world. However, nowadays technological development proceeds at a much more rapid pace and the operation of the above procedure for amending British practice has resulted in the British Standards falling behind the most economic modern practice as represented by a number of foreign codes.

As far as the export trade is concerned, British manufacturers may, and in fact do, as previously mentioned, quote on the basis of the regulations existing in the country where the plant is to be installed, provided, of course, that they are satisfied that the resulting product is in keeping with the standard of quality which they desire to uphold as a company. British manufacturers can, however, be placed at a disadvantage if the requirements with which they have to comply in the UK result in the installation of manufacturing plant in their works which requires capital expenditure greatly in excess of that necessary for the manufacture of lighter equipment acceptable abroad. It is also true to say that a programme of steel development that would best meet requirements in the UK may be less suitable as a means of serving trade abroad. It could possibly be claimed that the steelmaker would have to go to the expense of running two separate development programmes, one for home demand and one for export, which it must be admitted is an unsatisfactory state of affairs.

There is little doubt that lack of authoritative data on the properties of both standard steels and proprietary steels in this country has adversely influenced the engineering insurance companies, and other survey bodies, in considering proposals for increased stresses. It is notable that certain Continental steel manufacturers have done better in this respect, and have been rewarded by the adoption in their country of more enlightened ideas by the authorities responsible for boiler regulations and the like. Nevertheless, the steelmaker must know what class of data is going to be required, as it is wasteful and useless to produce unnecessary information. This being the case, those responsible for design should, first of all, determine in principle the basis upon which permissible stresses are to be determined; secondly, steelmakers should, with this knowledge, produce the necessary data; and thirdly, on the basis of the data the engineer should determine the magnitude of stress which can be tolerated.

Heat-treatment

Finally, mention must be made of the increasing importance of heat-treatment in the field of plate production. For a long time it was assumed quite correctly that thermal treatment would have little influence on those properties of mild-steel plate which were of significance in service. In consequence, most plates were supplied in the as-rolled condition, only a minority of the plate mills in this country having facilities for carrying out heat-treatment. Furthermore, once the plates were received by the customer, they might be heated to very high temperatures for bending, spinning, etc., and no significance was placed on the effect such thermal treatment might have on their properties. With the modern emphasis both in this country and abroad on such properties as notch ductility, the 0·2% proof stress at service temperature, rupture strength, etc., which depend on the structure of the steel to a much greater extent than does the ultimate tensile strength, the heat-treated condition of plates becomes of vital importance.

The data the steelmaker provides for such properties must be determined on material that is in the heat-treated condition in which it will go into service. The fabricator, in his turn, must ensure that at the end of the fabrication process the steel has the desired structure. With respect to both the above considerations, the latest foreign codes of practice are more explicit than the corresponding British Standard Specifications, and it is suggested that the necessary safeguards be written into British Specifications.

Realization of the importance of heat-treatment has led to a remarkable increase in the demand for plates to be supplied in the normalized condition. In the case of one particular mill, for example, producing about 200 000 tons of plates per year, the proportion of plates normalized has increased from 15% to nearly 25% during the last decade.

This trend has also opened the way for the steelmaker to extend the field of application for quenched and tempered plates. Quenching from the austenitic

TABLE V

Typical mechanical properties of carbon–manganese and low-alloy steels, quenched and tempered, for plates up to 1-in. thick

Steel type	Chemical composition, %									0·5% proof stress, tons in²	U T S tons in²	Elongation %, 4√A	Reduction of area, %	Charpy V-notch impact test	
	C	Si	S	P	Mn	Ni	Cr	Mo	V					Temp. °C, for 40 ft-lb	Temp. °C, for 50% fibre
Grain-controlled carbon–manganese	0·19	0·36	0·026	0·026	1·34	0·22	...	...	...	27	38	33	65	−40	−40
Low alloy	0·13	0·12	0·026	0·026	1·06	1·1	0·85	0·40	0·05	42	48	24	60	−50	−50

range is, of course, one of the most effective methods of achieving high strength in steel. For example, quenched and tempered alloy-steel plates have been used for many years for armour plate. In view of the extensive use of welding, it is of great significance that quenching is a most effective way of combining good weldability, good notch ductility, and high strength in plate material. While the most spectacular developments in this field have been brought about in the USA, the steelmakers in this country have been fully alive to the possibility of popularizing this class of material, and a very substantial tonnage of quenched and tempered plates has already been supplied for special structural purposes. As an example of the properties that can be achieved, Table V shows the composition and properties of a carbon–manganese and a low-alloy steel quenched and tempered in the form of 1-in. thick plate.

Fortunately there is today no problem in obtaining weld metal of sufficient strength to match such quenched and tempered steels, and the only two factors limiting their more widespread use are, on the one hand, the lack of adequate quenching plant at the steel mills and, on the other, the difficulty that may be encountered in carrying out all the necessary fabrication processes without heating the steel to a temperature at which the effect of quenching would be destroyed. However, both these limitations are of a type most likely to impede only the early stages of development of quenched structural steels, and the rapid increase in interest in this type of material is evidence that they are being overcome.

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New pre-refining process at Brymbo

STEELMAKING by pre-refining blast-furnace metal in a separate vessel then combining it with scrap in electric-arc furnaces has recently begun on a production scale at Brymbo Steel Works Ltd., near Wrexham. The process has been developed within the works with advice and assistance from BISRA.

Pre-refining takes place in special tilting furnace with a deep 16-ft dia. basic-lined hearth and high-alumina brick roof. The walls contain tangentially mounted oil burners which draw air through ducts beneath the furnace hearth, thus obtaining some preheat while helping to cool the hearth. There is provision for oxygen enrichment of this air feed.

Oxygen for pre-refining is supplied from a tonnage plant and injected through water-cooled lances, although additional 'dry' lances may be run over the furnace feed doors. The rate of oxygen injection is up to 800 ft/min.

Lime powder from a specially designed dispenser is jetted in with the oxygen.

Pre-refining time for a 20-ton charge of blast-furnace metal is between 1–1½ h, during which the metal temperature is raised from about 1 300° to 1 500° C or more. Little carbon is removed from the iron. Hearth depth, together with the use of oil burners in the furnace wall effectively controls foaming during the reaction.

Fume is removed through a large flue and chimney into the atmosphere, although it is intended to install fume cleaning plant.

At the end of the pre-refining period the metal is added to one of three 40-ton electric arc furnaces which already contains a half-charge of scrap at melting point.

Early figures show an oxygen consumption of 1 000 ft³/ton of metal from the pre-refining furnace (which includes 6·55% scrap in the charge) for an overall metal yield of 93%.

Considerable improvement of the process is expected with more operating experience, but because of its flexibility Brymbo engineers believe that the process could be applied to OH shops in the UK which are forced to use high-phosphorus blast-furnace metal.

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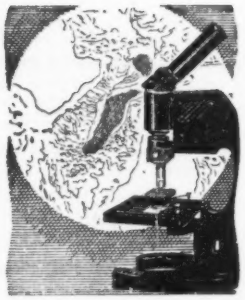

The inoculation of solidifying iron and steel castings by means of vibration

By J. H. Gittus, B.Sc., A.I.M.

SYNOPSIS

Balls of 2¼-in. dia., cast either in steel or in magnesium-treated cast iron and moulded either in graphite or in sand, have been vibrated during solidification at 100 c/s with an amplitude of 0·05 in. As a result, the columnar austenite-dendrites were eliminated from the central regions of the steel castings and were replaced by equiaxed crystals. Columnar dendrites persisted in the outer rim of the vibrated, graphite-moulded steel castings and, where they joined the equiaxed central region, a narrow zone of increased carbon, sulphur, manganese, silicon, nickel, chromium, and molybdenum contents was observed.

Magnesium-treated iron castings were inoculated by vibration, which in this respect resembles the conventional inoculants such as ferrosilicon. However, vibration appears to be a much more powerful inoculant than ferrosilicon. Thus it graphitized a chill-cast, magnesium-treated ball containing less than 0·2% silicon. In hyper-eutectic iron, which solidified too rapidly for graphitization to be produced, vibration conferred a random orientation upon the hyper-eutectic carbides.

Theories are proposed to explain these observations in terms of nucleation and growth during solidification. 1566

INTRODUCTION

GRAIN-REFINEMENT, degasification, and the emulsification of immiscible phases have been produced by the vibration of molten or solidifying metals. Most of the published work is concerned with non-ferrous alloys, particularly those of low melting point. An excellent review of the literature up to 1954 has been given by Hiedemann.[1]

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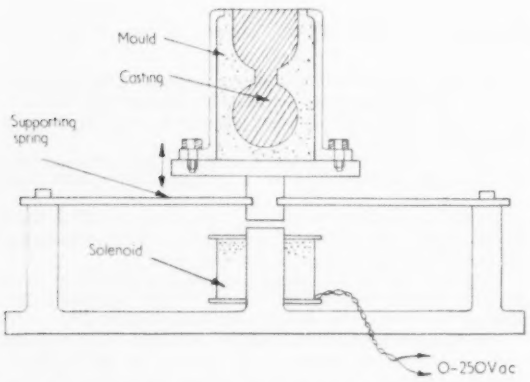


Fig. 1—Apparatus used to vibrate castings during solidification

Amongst the more extensive of the earlier investigations is that of Schmid, Ehret, and Roll,[2] who employed a magnetostrictive generator to produce ultrasonic vibrations which were used to secure grain-refinement in alloys of antimony, cadmium, and aluminium. In later experiments these authors studied the effects of the frequency and intensity of vibration upon the structure of Wood's metal, and subsequently found that vibration increased the rate at which iron was dissolved by molten zinc. Seeman and Menzel,[3] studying a continuous-casting process, produced grain-refinement by means of probes immersed in the liquid metal and vibrated magnetostrictively. A comparable application where mechanical or electrodynamic vibrations were induced in

TABLE I

Effect of vibrator voltage upon hardness and microstructure of sand-moulded, magnesium-treated cast-iron balls

Casting no.	Analysis, %							Vibrator voltage, V	BHN, as-cast	BHN, annealed	Microstructure, as-cast
	Chemical			Spectrographic							
	T.C.	S	P	Mg	Ni	Mn	Si				
1	3·50	0·005	0·04	0·125	0·80	0·32	1·25	0	415	...	White iron plus a few graphite spheroids
1V	...	...	...	...	...	...	...	150	412	...	" " " "
2	...	...	...	0·081	0·65	0·24	1·30	0	415	...	" " " "
2V	...	...	...	...	...	...	...	200	263	123	Grey iron with S.G.*
3	...	...	...	0·12	0·89	0·22	1·15	0	367	...	White iron plus a few graphite spheroids
3V	...	...	...	...	...	...	...	250	257	132	Grey iron with S.G.*

* Spheroidal graphite

Other elements in these irons and in those of Tables II and III were present as follows (percentage spectrographic analysis):

Ti	0·02	Sn	< 0·01	As	N.D.	Nb	N.D.
Cr	< 0·01	Al	0·01 to 0·03	Sb	N.D.	Ag	N.D
Mo	< 0·10	Bi	N.D.	Ca	< 0·002	Zr	N.D.
Cu	< 0·10	Th	N.D.	B	N.D.	Cd	N.D.
V	< 0·01	W	N.D.	Zn	N.D.	Be	N.D.
Pb	0·001	Te	< 0·01	Ce	N.D.		

N.D. = Not detected

continuously cast ingots of aluminium–copper–magnesium alloys is described by Mann,[4] who noted a reduction in grain-size but an increased tendency for cracks to form. By vibrating the mould, Richards and Rostoker[5] secured grain-refinement in ingots of an aluminium alloy. A similar alloy was studied by Southgate,[6] who observed grain-refinement in the vicinity of a vibrating probe immersed in one end of a horizontal-bar casting. More recently, Freedman and Wallace[7] and Freedman, Wallace, and Carbonaro,[8] by vibrating ingots of copper and aluminium alloys, obtained grain-refinement and an associated improvement in mechanical properties.

The recent work of Mastalerz[9] is of interest since it

TABLE II

Relative and cumulative effects of ladle-inoculation and vibration upon hardness and microstructure of magnesium-treated cast-iron balls

Casting no.	Analysis, %							Type of mould	Type of inoculant	Vibrator voltage, V	BHN, as-cast	BHN, annealed	Microstructure, as-cast
	Chemical			Spectrographic									
	T.C.	S	P	Mg	Ni	Mn	Si						
4	4·20	0·007	0·04	0·037	0·38	0·14	0·13	Sand	Nil	0	545	256	White-iron, no graphite
4V	...	...	...	...	...	...	...	"	"	250	202	102	$\frac{1}{16}$-in. white-iron rim, grey-iron core with S.G.†
5	...	...	...	0·048	0·79	0·15	0·80	"	0·625% FeSi*	0	278	194	Slight white-iron rim, grey-iron core with S.G.†
5V	...	...	...	...	...	...	...	"	"	250	238	122	" " "
6	4·15	0·007	0·04	0·044	0·75	0·16	0·12	"	1·2% graphite	0	514	378	White-iron, no graphite
6V	...	...	...	...	...	...	...	"	"	250	309	177	$\frac{1}{8}$-in. white-iron rim, grey-iron core with S.G.†
7	...	...	...	0·115	0·68	0·14	0·64	"	1·2% graphite, 0·625% FeSi*	0	283	146	Slight white-iron rim, grey-iron core with S.G.†
7V	...	...	...	...	...	...	...	"	"	250	233	115	" " "
8	...	...	...	0·051	0·74	0·13	0·15	Graphite	Nil	0	508	185	White-iron, no graphite
8V	...	...	...	...	...	...	...	"	"	250	332	130	$\frac{1}{8}$-in. white-iron rim, grey-iron core with S.G.†
9	...	...	...	0·035	0·62	0·19	0·60	"	0·625% FeSi*	0	497	150	White-iron, no graphite
9V	...	...	...	...	...	...	...	"	"	250	375	139	$\frac{1}{8}$-in. white-iron rim, grey-iron core with S.G.†

* 80% Si, balance substantially iron

† Spheroidal graphite

TABLE III

Production of graphitic S.G. iron balls, in graphite-moulds, by ladle inoculation, vibration, or both treatments

Casting no.	Analysis, %							Type of inoculant	Vibrator voltage, V	BHN as-cast	BHN annealed	Spheroids per mm², annealed	Microstructure, as-cast
	Chemical			Spectrographic									
	T.C.	S	P	Mg	Ni	Mn	Si						
10	...	...	...	...	...	...	...	Nil	0	405	143	163	White-iron, some S.G.† at centre
10V	4·45	0·009	0·038	0·076	0·66	0·36	1·7	,,	250	287	148	720	$\frac{1}{8}$ in. white-iron rim, grey-iron core with S.G.†
11	...	...	...	...	...	...	...	0·625% FeSi*	0	331	158	360	Mottled iron
11V	...	...	...	0·071	0·59	0·31	1·95	,,	250	274	155	750	$\frac{1}{8}$-in. white-iron rim, grey iron core with S.G.†
12	...	...	...	...	...	...	...	1·20% graphite	0	459	139	150	White iron, some S.G.† at centre
12V	4·42	0·008	0·037	0·081	0·73	0·26	1·6	,,	250	302	150	760	$\frac{1}{8}$-in. white-iron rim, grey-iron core with S.G.†
13	...	...	...	...	...	...	...	1·20% graphite 0·625% FeSi*	0	361	159	480	Mottled iron
13V	...	...	...	0·054	0·60	0·35	1·75	,,	250	276	152	870	$\frac{1}{8}$-in. white-iron rim, grey-iron core with S.G.†

* 80% Si, balance substantially iron † Spheroidal graphite

suggests that porosity in steel may be reduced by vibration, whilst Jagaciak and Jones,[10] studying mock turbine-blades cast in an alloy steel, found an improvement in room-temperature mechanical properties attributable to vibration.

The only reported observation for cast iron appears to be that of Richards and Rostoker,[5] who found that the size of the graphite flakes in an iron casting could be increased by vibrating it during solidification. The effects of vibration upon iron castings appeared to merit further attention, if only because of the lack of existing information. Accordingly, an investigation was made, coupled with a parallel study of the influence of vibration upon steel castings. The results are reported in the present paper.

APPARATUS AND GENERAL PROCEDURE

Most of the iron castings were made from metal which had been melted in an oil-fired crucible furnace and which had a residual magnesium content of the order employed for the production of spheroidal graphite.[11] Castings were also made in a nickel–chromium–molybdenum steel (similar to BS. En 24) and in a 1·4% carbon unalloyed steel, both of which were melted in a small, basic-lined, high-frequency furnace. The castings were spheres of $2\frac{1}{4}$ in. dia. and surmounted by a feeder into which the metal was poured (*a*) at 1 400° C (S.G. iron), and (*b*) at 1 540° C (both steels).

The moulds were either machined from graphite electrodes or rammed-up in silica sand bonded by the CO_2/sodium–silicate process. A comparison of the results obtained in these two moulding materials made possible an appraisal of the effects of solidification rate.

A simplified drawing of the apparatus used to vibrate the castings during solidification is shown in Fig. 1. The mould was attached to an armature which was supported by a spring and vibrated at 100 c/s by an a.c. mains-energized solenoid. The spring length was adjusted to produce resonance when a maximum amplitude of 0·050 in. was obtained at an applied voltage of 250 V. Lower voltages, obtained by means of a transformer, gave smaller amplitudes.

After examination in the ' as-cast ' condition, some of the iron castings were annealed in boxes of iron turnings. In all such cases the annealing treatment was:

8 h at 900° C, transferred to furnace at 690° C
16 h at 690° C, box-cooled to room temperature.

In most cases Brinell hardnesses were measured both in the as-cast condition and after annealing. The hardness impressions were made in a region 1 in. distant from the edges of the balls.

PROCEDURE AND RESULTS: CAST IRON

(a) Influence of amplitude of vibration

A number of taps were taken from a crucible of molten iron and treated with nickel–magnesium. From each tap, two sand-moulded $2\frac{1}{4}$-in. dia. balls were cast. In each case, one of the moulds was vibrated, and the other was not. Amplitude of vibration was varied by varying the voltage applied to the solenoid, and was different for each tap. Vibration was continued until the castings were solid. When cold, they were sectioned to provide specimens for micro-examination and hardness measurement. Selected specimens were then annealed.

Analyses, vibrator-voltages, microstructures, and Brinell hardnesses are shown in Table I. All of the unvibrated balls were substantially free from graphite, as had been anticipated, since magnesium is a powerful carbide-stabilizer. The balls which were vibrated by applying 200 or 250 V to the solenoid were completely graphitized and had good spheroidal-graphite structures. Vibration at the higher amplitudes had therefore acted as an inoculant, and accordingly the following experiments were made to compare its

effects with those of inoculation by means of ferrosilicon or carbon.

(b) Relative and cumulative effects of vibration and ladle inoculation

An iron containing less than 0·2%Si was used in this experiment because its low graphitizing tendency offered a critical test of the efficacy of vibration as an inoculant. The iron was melted in a crucible furnace and taps were taken, treated with nickel–magnesium, and cast into vibrating and stationary (reference) moulds. Maximum amplitude of vibration (about 0·050 in.) was used, and both sand and graphite moulds were studied. In some cases the metal was inoculated immediately before casting, either with ferrosilicon, or with crushed electrode-carbon, or with both materials simultaneously. The experimental procedure and the results obtained are shown in Table II, from which the following conclusions have been drawn:

(i) Despite the low silicon content, vibration has substantially graphitized the sand-moulded ball *4V* and the graphite-moulded ball *8V*. An as-cast structure of this type has never previously been reported for irons of such a composition

(ii) Vibration has graphitized the graphite-moulded ball *8V*, but inoculation with ferrosilicon has not graphitized the otherwise similar ball *9*

(iii) Comparison of balls *6* and *4* indicates that crushed electrode-carbon has not acted as an inoculant, and a comparison of balls *5* and *7* suggests that it has not supplemented the inoculating effect of ferrosilicon when the two substances were used together

(iv) Comparing *5* with *5V*, *7* with *7V*, and *9* with *9V*, the inoculating effects of vibration and ferrosilicon are seen to have been additive, since in each case the vibrated ball is the softer of the two.

(c) Vibration of graphite-moulded ball castings

The graphitization of the graphite-moulded ball *8V* was of particular interest since it suggested that by means of vibration it would be possible to produce chill-moulded S.G. iron castings having substantially graphitic structures in the as-cast condition, particularly if metal of conventional silicon content were employed instead of the low-silicon iron used for ball *8V*.

Pursuing this point, further graphite-moulded balls were made with silicon and carbon contents higher than those of the irons shown in Table II, to favour graphitization. The metal was treated with nickel–magnesium and in some cases was inoculated before pouring. Castings were made in moulds vibrating at the maximum amplitude and also in stationary (reference) moulds. The results, summarized in Table III, show that vibration has again acted as a powerful inoculant, producing balls consisting of grey-iron cores and thin white-iron rims. The persistence of the white-iron rim, despite the use of high carbon and silicon contents, is attributable to the very high solidification rate near to the mould wall, which appears to preclude graphitization of the rim even when circumstances are particularly favourable.

Most of the conclusions which were drawn from the

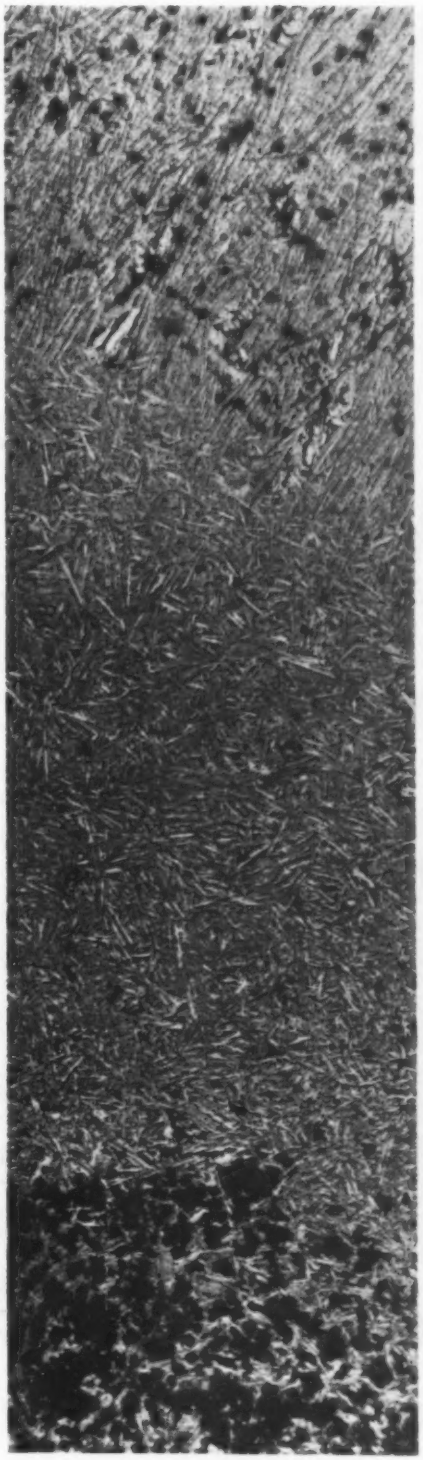
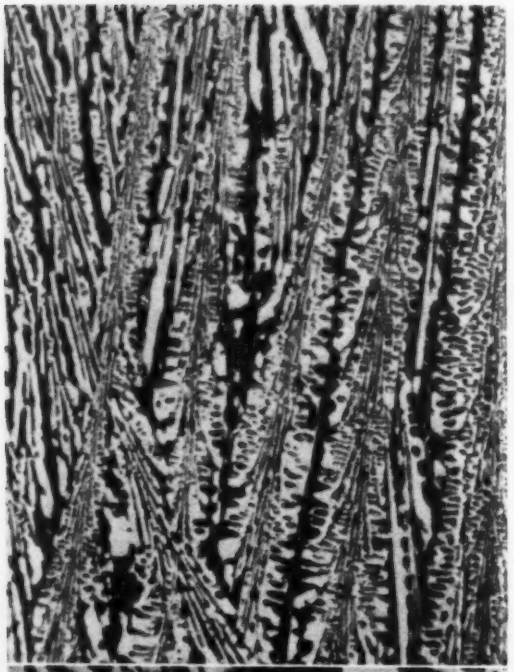


Fig. 2—Structure near edge of graphite-moulded vibrated cast-iron ball 10V. Etched in 2% Nital × 30



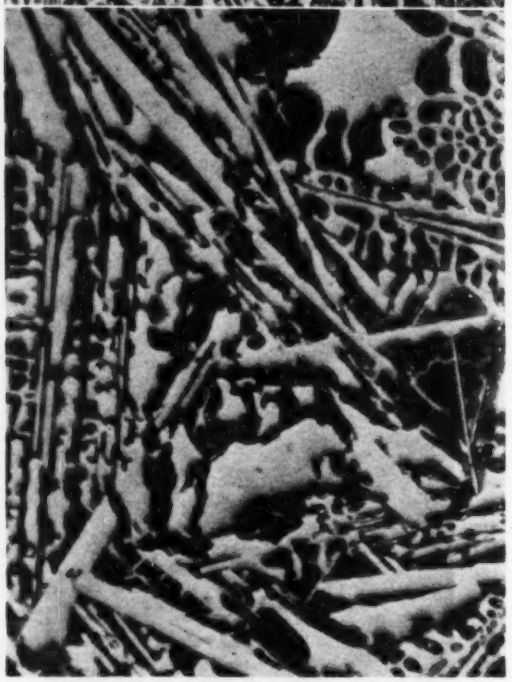


Fig. 3 (*top*)—**Zone *A* of Fig. 2 at higher magnification to show columnar structure, etched in 2% Nital** × **500**

Fig. 4—Zone *B* of Fig. 2 at higher magnification to show random orientation of carbides. Etched in 2% Nital × **500**

results presented in Table II are substantiated by those reported in Table III. The Brinell hardness measurements show that the inoculating effects of a ladle addition of ferrosilicon and of mould-vibration have again been additive and the suggestion that vibration has been a more powerful inoculant than 0·625% of ferrosilicon is sustained by these further data.

Further information regarding the inoculating effects of vibration and ferrosilicon was obtained by counting the number of spheroids per square millimetre of a zone about 1 in. from the edge of each annealed ball. The figures so obtained are proportional to the rates at which eutectic cells (each of which has, as its centre, a graphite spheroid) were nucleated during solidification. Since the principal effect of inoculation in S.G. iron is to increase the rate at which the iron–graphite eutectic is nucleated, the efficiency of an inoculant may be measured by a spheroid-count. At fixed levels of all other variables, the more potent the inoculant, the greater will be the number of spheroids which it produces. On this basis, the spheroid-counts listed in Table III clearly confirm that vibration has been a more powerful inoculant than the ferrosilicon addition. As would be expected, an increase in the number of spheroids was accompanied by a decrease in their size.

In the as-cast condition the vibrated balls exhibited four distinct structural zones, three of which are shown in Fig. 2. Near to the mould was a layer of equiaxed white iron, about 0·010 in. thick. This structure, which is typical of chill-moulded cast irons, was observed in both the stationary and the vibrated balls, and is not illustrated. Further from the mould wall a band of hyper-eutectic white iron occurred: zone *A* in Fig. 2. It had the columnar structure shown in Fig. 3 and was observed in both vibrated and stationary balls. However, in the unvibrated balls this type of structure extended to the centre of the casting (with gradual loss of the radial orientation illustrated in Fig. 3), whilst in the vibrated balls it gave place to the randomly orientated white-iron structure shown as zone *B* in Fig. 2 and (at higher magnification) in Fig. 4. It is believed that in zone *B* cooling rates were too high to permit graphitization, despite the inoculating effect of the vibration, and that instead a modification of the growth habit of the white iron occurred. On this hypothesis, the persistence of the columnar structure in zone *A* of the vibrated balls would denote a rate of solidification too high to permit even the re-orientation of the white-iron crystallites by vibration. Conversely, zone *C*, the central zone, would be a region in which solidification was slow enough to permit graphitization of the iron by vibration.

The effects of vibration and of cooling rate are evidently complementary, the effect produced by the former depending largely on the latter. Furthermore, crystallite re-orientation and graphitization are distinctly separate effects, so that the former might be anticipated in cases where the latter is impossible. Thus in certain circumstances the graphitizing effect of vibration can be completely suppressed when the zone of randomly orientated crystallites extends to the centre of the casting. The properties of such white irons will be dealt with in a further paper. Addition-

TABLE IV

Analysis of graphite- and sand-moulded steel balls

Casting no.	Analysis, %†								Type of steel	Type of mould
	Chemical			Spectrographic						
	T.C.	S	P	Ni	Mn	Si	Cr	Mo		
14 (14V)	0·44	0·01	0·04	1·80	0·62	0·56	1·35	0·33	En 24	Graphite
15 (15V)	0·44	0·008	0·03	1·75	0·65	0·42	1·35	0·30	En 24	Sand
16 (16V)	1·14	0·009	0·04	< 0·1	0·44	0·58	0·058	< 0·1	Plain carbon	Graphite
17 (17V)	1·13	0·009	0·04	< 0·1	0·46	0·40	0·066	< 0·1	Plain carbon	Sand

Final deoxidation was by means of 0·05% Al

† Other trace elements, with the exception of Cu (0·03%) generally below spectrographic threshold (cf. Table I)

ally, the castings in Table III were all hyper-eutectic, and much of the carbide visible in their rims was undoubtedly primary carbide precipitated before the eutectic solidified. One of the reasons for the unique structure of the white-iron zone *B* is, therefore, that vibration 'randomized' the orientation of the primary carbides. It was of interest to ascertain whether it would similarly affect primary austenite dendrites, and this possibility was studied by means of steel castings.

PROCEDURE AND RESULTS: STEEL

Two steels were chosen for investigation. One was an En 24 type, hypo-eutectoid low-alloy steel; the other an unalloyed steel of hyper-eutectoid carbon content (Table IV). As before, 2¼-in. balls were cast in both stationary and vibrating, graphite moulds and sand moulds. Maximum amplitude of vibration (0·050 in.) was employed.

Examination of sectioned balls showed that the dendrite structure had been modified by vibration. Figures 5 and 6 show the coarse, columnar dendrites in the stationary, graphite-moulded En 24 ball, whilst Figs. 7 and 8 demonstrate that equiaxed dendrites were produced when an otherwise similar ball was vibrated. As in the cast-iron balls (Fig. 2), an outer rim of columnar crystallites still remained in the vibrated steel ball: the junction of the columnar and the equiaxed zones is seen in Fig. 7.

The sand-moulded En 24 steel balls had equiaxed dendrites throughout their section, whether they had been vibrated or not, but the dendrites were coarser

Fig. 5—Columnar dendrites near edge of 'stationary' graphite-moulded En 24 steel ball *14*. Etched in Fry's reagent × 20

Fig. 6—Columnar dendrites of variable orientation near centre of 'stationary' graphite-moulded En 24 steel ball *14*. Etched in Fry's reagent × 20

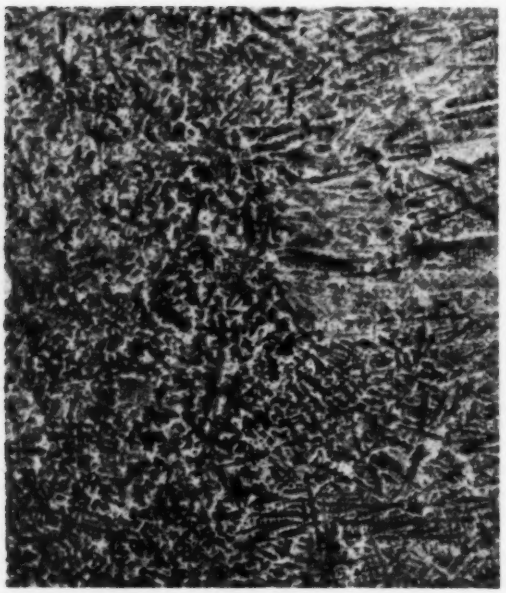


Fig. 7—Junction of columnar and equiaxed dendrites near edge of vibrated graphite-moulded En 24 steel ball *14V* (edge of ball is to right of picture). Etched in Fry's reagent × 20

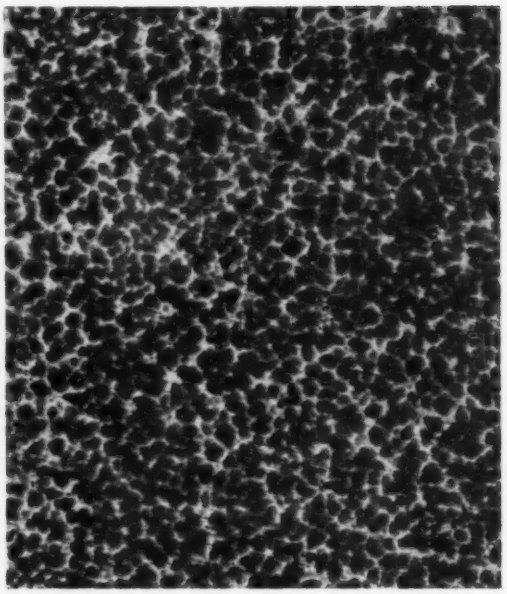


Fig. 9—Coarse equiaxed dendrites in 'stationary' sand-moulded En 24 steel ball *15*. Etched in Fry's reagent × 20

in the stationary ball (Fig. 9) than in its vibrated counterpart (Fig. 10).

A rather different picture is presented by the plain carbon-steel balls. Those cast into stationary graphite moulds had columnar dendrites (Figs. 11 and 12) but these were completely eliminated by vibration, even from the rim of the casting, which instead had a fine, equiaxed structure (Fig. 13), giving place to a coarser, equiaxed zone in the centre of the ball (Fig. 14).

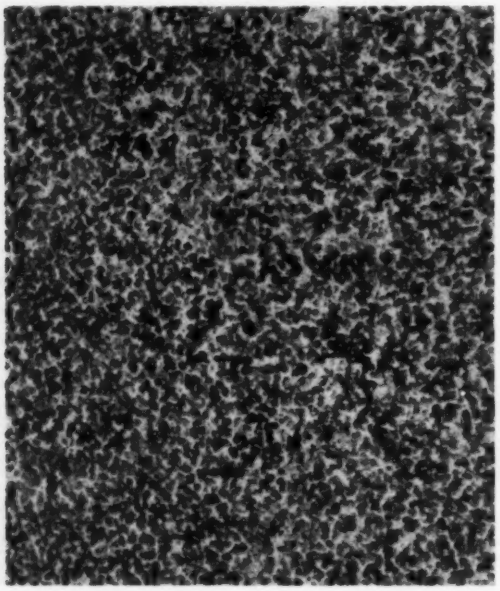


Fig. 8—Equiaxed dendrites near centre of vibrated graphite-moulded En 24 steel ball *14V*. Etched in Fry's reagent × 20

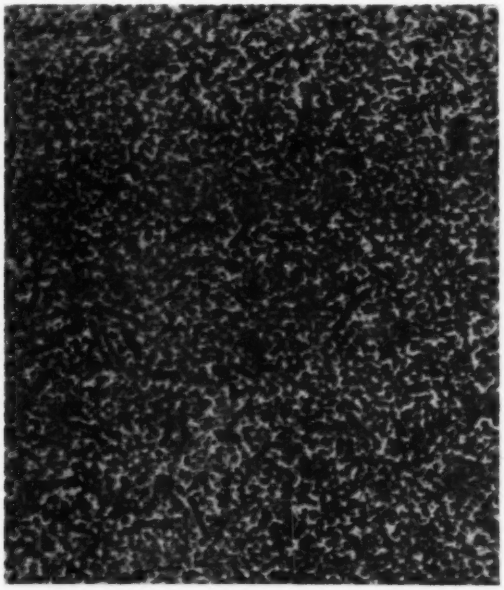


Fig. 10—Fine equiaxed dendrites in vibrated sand-moulded En 24 steel ball *15V*. Etched in Fry's reagent × 20

Fig. 11—Columnar dendrites near edge of 'stationary' graphite-moulded plain-carbon steel ball *16*. Etched in Fry's reagent × 20

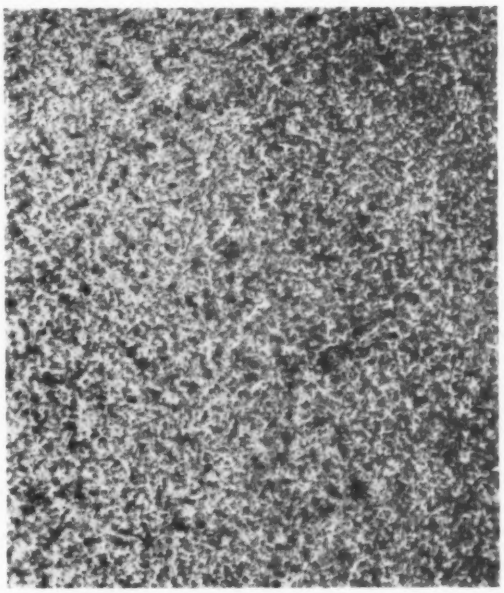


Fig. 13—Junction of fine- and medium-sized equiaxed dendrites near edge of vibrated graphite-moulded plain-carbon steel ball *16V* (edge of ball is to right of picture). Etched in Fry's reagent × 20

Despite these differences in dendrite-structure, no modification in austenite grain-size attributable to vibration was in any case detected.

The stationary, sand-moulded carbon-steel ball had a structure of columnar dendrites (Fig. 15), unlike the comparable En 24 ball of Fig. 9, in which the dendrites were equiaxed. Vibration caused the

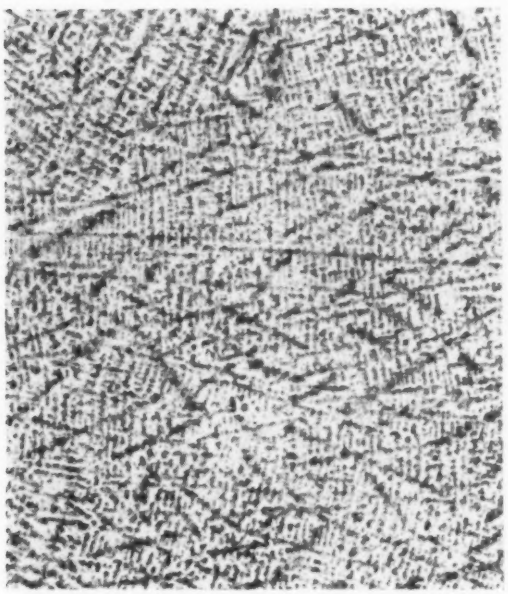


Fig. 12—Columnar dendrites of variable orientation near centre of 'stationary' graphite-moulded plain-carbon steel ball *16*. Etched in Fry's reagent × 20

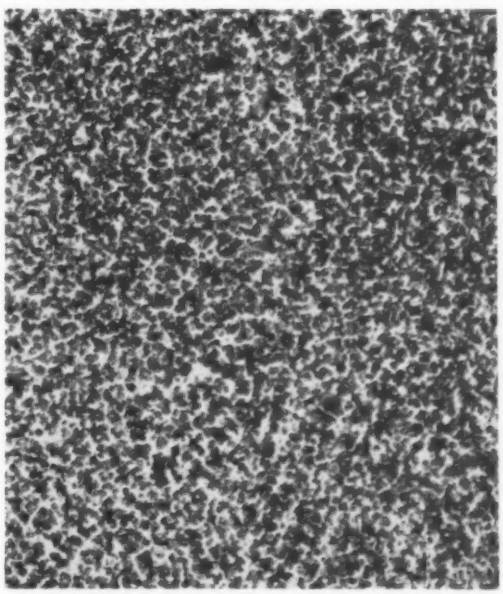


Fig. 14—Medium-sized equiaxed dendrites near centre of vibrated graphite-moulded plain-carbon steel ball *16V*. Etched in Fry's reagent × 20

Fig. 15—Columnar dendrites on 'stationary' sand-moulded plain-carbon steel ball *17*. Etched in Fry's reagent × 20

columnar structure to be replaced by rather coarse, equiaxed dendrites (Fig. 16).

Vibration appears to have reduced the size of the central shrinkage-cavities in the graphite-moulded balls which, however, were found to have a banded

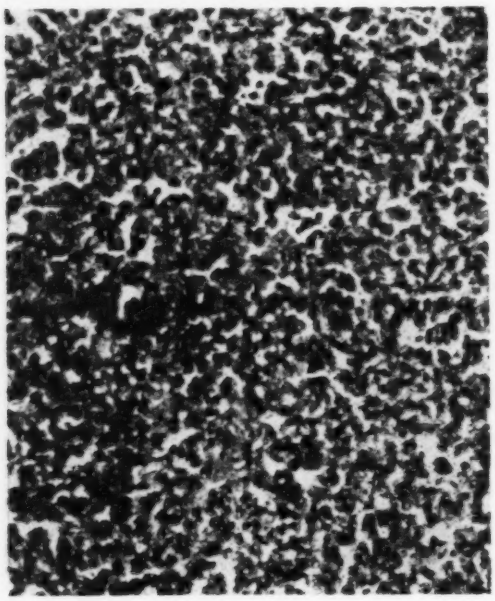


Fig. 16—Coarse equiaxed dendrites in vibrated sand-moulded plain-carbon steel ball *17*. Etched in Fry's reagent × 20

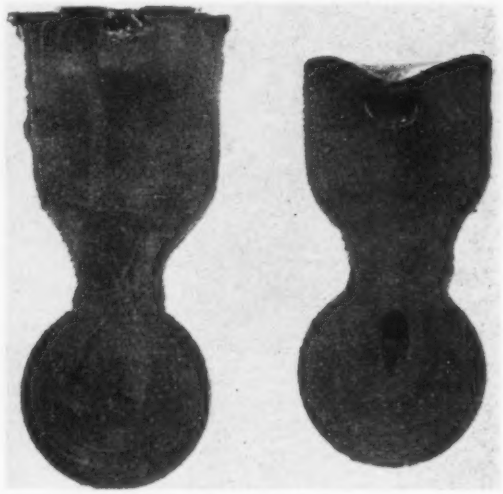


Fig. 17—Sections through graphite-moulded En 24 steel balls, showing (*left*) banded structure produced in ball *14V* by vibration, and (*right*) absence of this structure from the corresponding 'stationary' ball *14*. Etched in Humphrey's reagent (12% aqueous solution of cuprous ammonium chloride) × ½

structure not evident in the stationary balls (Figs. 17 and 18). In each ball, the most marked 'band' corresponded to the junction of the rim-structure and the core-structure and had a higher sulphur content than its surroundings (Fig. 19).

Evidence of segregation of other elements as well as of sulphur was obtained. For example, about 20% of ferrite was present in the general structure of the graphite-moulded En 24 balls *14* and *14V* (Fig. 20),

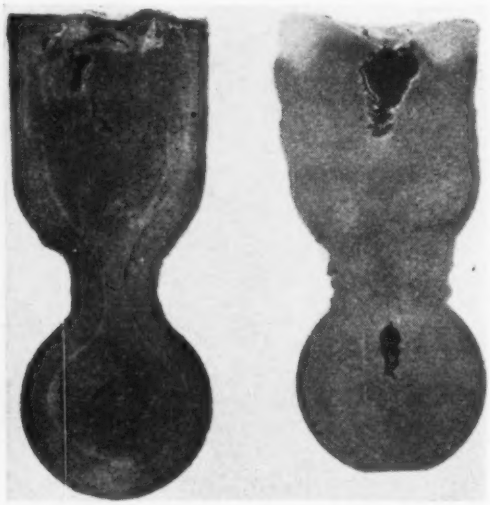
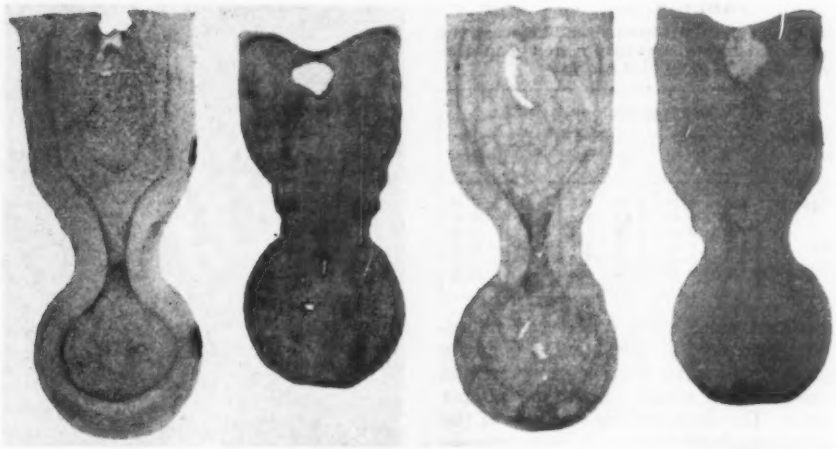


Fig. 18—Sections through graphite-moulded plain-carbon steel balls showing banded structure produced in ball *16V* (*left*) by vibration, and absence of this structure from corresponding 'stationary' ball *16* (*right*). Etched in Humphrey's reagent × ½



14V 14 16V 16

Fig. 19—Sulphur prints of graphite-moulded balls showing sulphur segregation corresponding to banded structures of vibrated balls (cf. Figs. 17 and 18) × ½

but ferrite was virtually absent from the band of high sulphur content at the junction between the columnar rim and the equiaxed core of ball *14V*. Furthermore, the plain carbon-steel balls generally had a pearlitic structure, except in the band of high sulphur content where a grain-boundary network of pro-eutectoid cementite was observed (Fig. 21). Segregation of carbon as well as of sulphur appears, therefore, to have occurred in both steels. A spectrographic survey of the vibrated, graphite-moulded En 24 ball showed that the band was also the site of concentration of silicon, nickel, manganese, chromium, and molybdenum (Table V). Detailed microexamination revealed occasional microporosity in the same region (Fig. 22).

No bands were revealed in the vibrated sand-moulded balls of either steel when examined either by etching or sulphur-printing. This might be anticipated, since in the sand-moulded balls there was no difference between rim structure and core structure and therefore no junction between regions of dissimilar structure, comparable to the area in which segregation was found in the graphite-moulded balls. This difference between sand- and graphite-moulded balls can only be a function of their different cooling rates.

Although vibration promoted macro-segregation in

Fig. 20—Widmanstätten ferrite in general structure of 'stationary' graphite-moulded En 24 steel ball *14*. Etched in saturated picral × 160

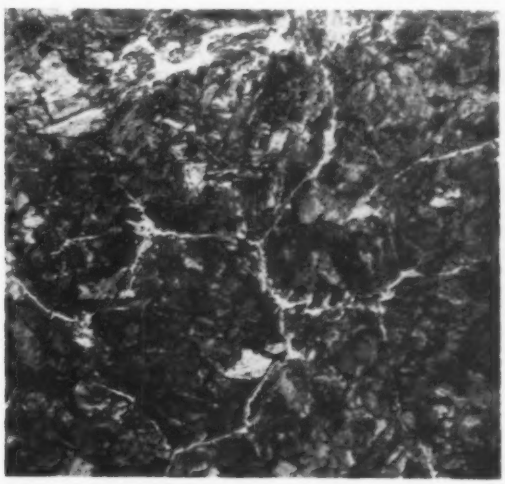


Fig. 21—Grain-boundary precipitate of pro-eutectoid carbide confined to band of high sulphur content in vibrated graphite-moulded plain-carbon steel ball *16V*. Etched in 2% Nital × 300

TABLE V

Segregation of alloying elements in the band between the columnar and equiaxed crystallites in vibrated graphite-moulded En 24 steel ball no. *14V*

Position of spark crater	Spectrographic analysis, %					
	Ni	Mn	Si	Cr	Mo	Ti
Near left-hand edge	1·8	0·62	0·58	1·3	0·31	< 0·01
On 'band' (left)	1·95	0·66	0·62	1·4	0·38	< 0·01
Mid-radius (left)	1·8	0·62	0·56	1·3	0·33	< 0·01
Mid-radius (right)	1·7	0·63	0·58	1·3	0·32	< 0·01
On 'band' (right)	1·9	0·67	0·60	1·4	0·38	< 0·01
Near right-hand edge	1·8	0·59	0·54	1·3	0·30	< 0·01

the graphite-moulded steel balls, it reduced micro-segregation. For example Fig. 23 shows a dendrite (in a stationary ball) which has been so impoverished of alloying elements by 'coring' as to be almost completely ferritic. The dark-etching outlines of the dendrites denote regions to which the alloying elements have segregated. The vibrated counterpart of the ball in Fig. 23 exhibits a much more uniform distribution of ferrite (Fig. 24), and a simultaneous reduction in the proportion of dark-etching, segregated regions which outline the dendrites. This is taken to be a direct consequence of the higher surface area per unit-volume of the equiaxed crystallites, which favours the elimination of segregation and coring by facilitating diffusion of elements from the enriched interdendritic regions into the impoverished dendrites. The function of surface area in this context is analogous to its effect on the rate of cooling of a heated body. In the latter case, a high surface area per unit-volume promotes rapid outward flow of heat, whilst in the former case it promotes rapid inward diffusion of alloying elements. The reduction in micro-segregation is thus readily explained. The macro-segregation produced by vibration is more puzzling, but the following hypothesis appears reasonable. In Fig. 25 sections through a vibrated casting (*A* and *B*) and a stationary casting (*C* and *D*) are shown during the early stages of solidification (*A* and *C*) and after solidification (*B* and *D*). It is assumed that the refinement of crystal structure produced by vibration is evidence of an increase in the rate of nucleation, and of a consequent reduction in the amount of undercooling which must occur before solidification can begin. The latter contention is supported by the literature.[12]

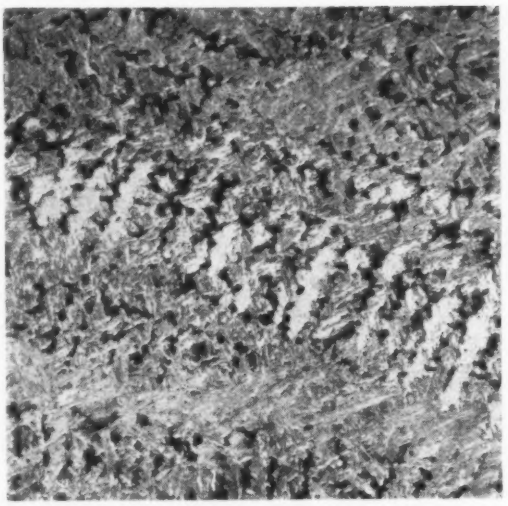


Fig. 23—Cored dendrite exhibiting a substantially ferritic structure in 'stationary' graphite-moulded En 24 steel ball *14*. Etched in saturated picral + 0·5%HNO_3 × 50

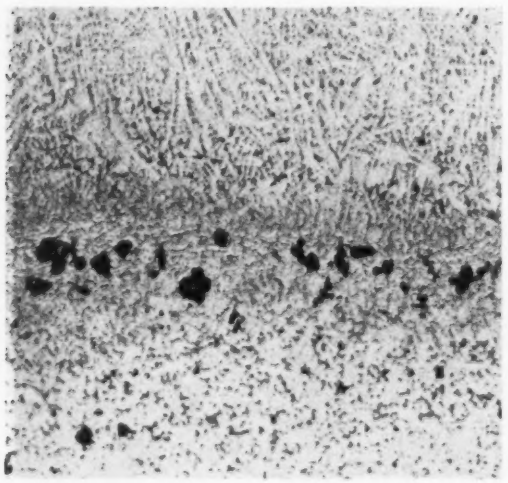


Fig. 22—Porosity at junction of columnar and equiaxed dendrites in vibrated graphite-moulded En 24 steel ball *14V*. Etched in saturated picral + 0·5%HNO_3 × 20

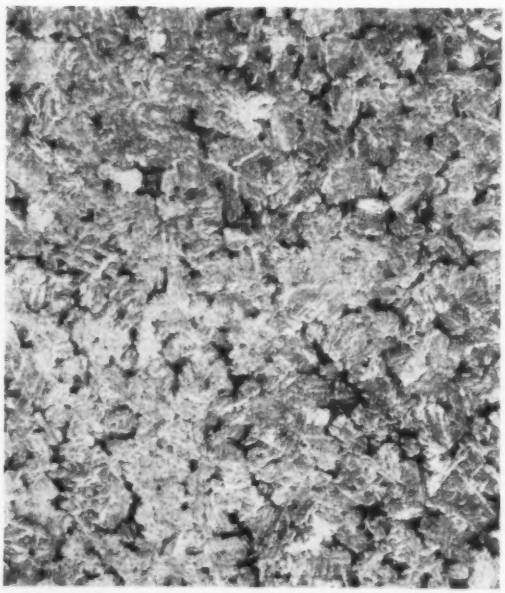


Fig. 24—Reduction in 'coring' attributable to vibration (vibrated counterpart of ball shown in Fig. 23). Etched in saturated picral + 0·5%HNO_3 × 50

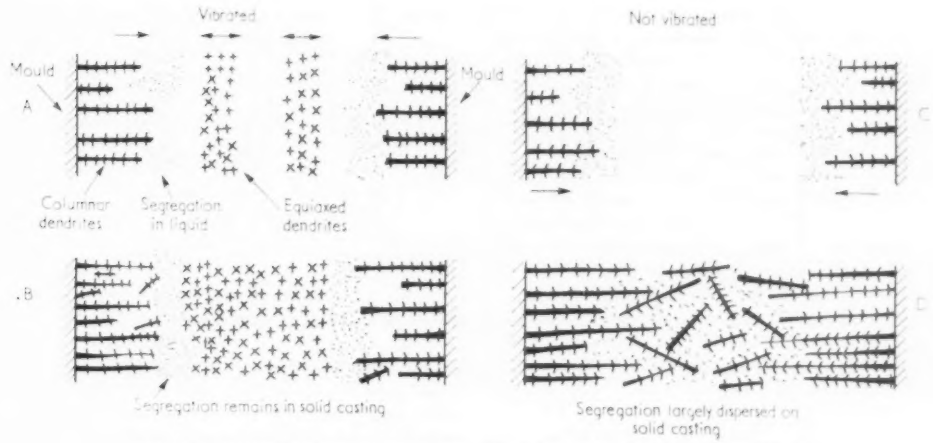


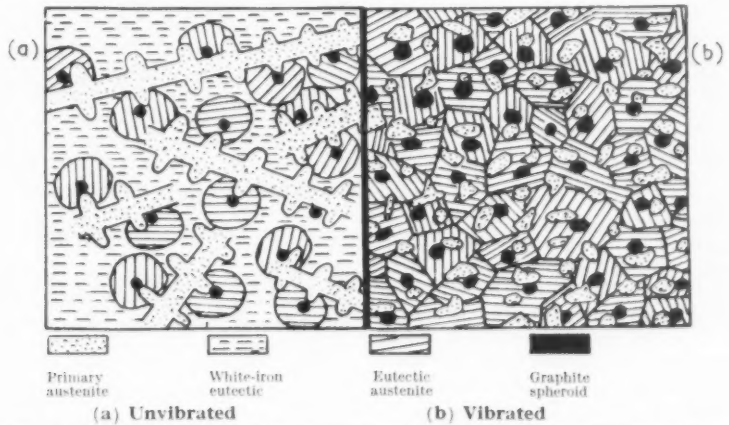
Fig. 25—Solidification pattern for vibrated and stationary castings

Initially, columnar dendrites grow inwards from the surfaces of both castings, the rate of cooling near the surface being so great that insufficient time is available for many nuclei to be formed, even under the influence of vibration. In both vibrated and stationary castings initial solidification therefore occurs principally by the extension of a few large dendrites.

The presence of a segregated band at the junction of columnar and equiaxed zones in the vibrated steel balls strongly suggests that the band was one of the last regions to solidify. If this is so, it implies that a stage is reached when an inner zone, isolated by liquid metal from both the centre and the columnar rim, attains a temperature at which, under the nucleating influence of vibration, solidification can begin. Nearer to the centre the metal is too hot to solidify, whilst nearer to the solidifying rim the metal has cooled too rapidly for vibration to produce any nuclei. This is illustrated in Fig. 25*a*. This line of reasoning is tantamount to suggesting that, since vibration prevents undercooling from occurring in the central regions of a casting,[12] these regions can start to freeze at a higher temperature than the rim, and that solidification therefore proceeds simultaneously at the edge and in some central region, the final junction of the solidification fronts being the segregated band.

Metal in advance of the solidification front is enriched in alloying elements. In the case of the stationary casting this enriched liquid moves inwards as solidification proceeds, is dispersed in the process and, in the solid state, appears as micro-segregation. In the vibrated castings, however, the enriched liquid is trapped by the outward growth of the solidifying equiaxed zone and by the inward growth of the columnar rim zone, so that a band of high alloying-element content occurs at the junction of the columnar zone with the equiaxed zone. Porosity in this band is similarly explained, since when the band finally freezes it is virtually isolated from the feeder by the solidified regions on either side.

On this hypothesis, a reduction in the general cooling rate should reduce the depth of the columnar rim in a vibrated casting, thereby moving the segregated band towards the surface of the casting. This assumption is substantiated by the vibrated sand-



(a) Unvibrated **(b) Vibrated**

Fig. 26—Influence of vibration upon number of spheroids, attributable to refinement of primary austenite dendrites

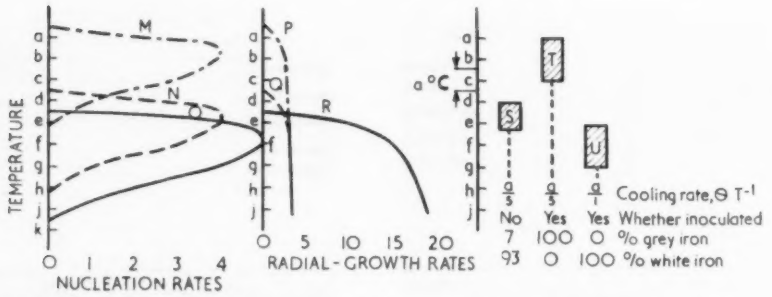


Fig. 27—Diagram to illustrate proposed theory of eutectic solidification (*see text*)

moulded castings, which showed neither a columnar zone nor associated macro-segregation.

DISCUSSION

Three distinct structural modifications, attributable to vibration, have emerged as a result of this investigation:

(i) Refinement of primary austenite dendrites in steel (and also, it may safely be concluded, in cast iron)
(ii) Refinement of primary carbide in hyper-eutectic white cast iron
(iii) Graphitization during solidification of cast iron.

Each effect may be attributed to an increase in the nucleation-rate of the specific phase or phases. In (i) the vibration may deflect the austenite dendrites from their normal, radial path, thereby causing impingement of neighbouring dendrites and consequent interference with (or cessation of) their growth. Further solidification would then entail the nucleation of more dendrites. Alternatively, or additionally, tensile waves caused by reflection of the vibrations may actually shatter dendrites larger than a certain critical size. Similar arguments can be applied to explain observation (ii).

Effect (iii) is equivalent to an increase in the rate at which the stable iron–graphite eutectic is nucleated. In hypo-eutectic irons this may be partly due to the prior production, by vibration, of small austenite dendrites having a surface area greater than that of the coarser dendrites found in ' stationary ' castings. One preferred site for nucleation of the iron–graphite eutectic is the dendrite/melt interface, and, by increasing the area of this interface, vibration should favour an increase in the rate of eutectic-nucleation, (Fig. 26). This effect cannot be invoked to explain the behaviour of vibrated, hyper-eutectic castings, since they contain no austenite dendrites. In such cases vibration causes the primary carbide to be replaced by primary graphite, and also favours the formation of the iron–graphite eutectic. Both effects must be mainly due to an increase in the rate at which nucleation of the appropriate phase occurs from the liquid metal, and in this respect the effects of vibration resemble those of the more conventional inoculants, such as ferrosilicon. An increase in the rate at which the iron–graphite eutectic is nucleated from the liquid metal is probably produced also by vibrating hypo-eutectic irons, supplementing the effects produced by the increased surface area of the austenite dendrites referred to above.

The mechanisms of eutectic-solidification in cast iron, especially the effects of cooling rate and inoculation, are not properly understood. The observations reported in this paper re-emphasize this lack of understanding and have prompted an attempt to formulate a complete description of the eutectic process in terms of three parameters: nucleation rate, growth rate, and rate of heat abstraction. The development of this concept is discussed below.

Proposed theory of eutectic solidification

Solidification proceeds by nucleation and subsequent growth of cells. Many similar mechanisms have been analysed by previous workers and have been described, by means of equations, in terms of their nucleation- and growth-rates. In the mathematical techniques employed for such cases, however, isothermal conditions are commonly postulated. These methods cannot be used for the analysis of the eutectic process, in which temperature is a variable.

For the sake of simplification, heat abstraction is approximated by a discontinuous process, in which the casting, having remained at temperature q for time Δt_q, cools instantaneously to a temperature $\Delta\theta$ lower, where it remains for a further interval of time.

Consider unit volume of a solidifying iron casting of eutectic equivalent-carbon content. The number of eutectic cells nucleated during a brief interval of time, Δt_q, will be

$$\Delta N_q = \Delta t_q \, V_q \, N_q$$

where V_q is the fraction of the total volume which is liquid, N_q is the number of nuclei which form in unit volume of liquid during unit time, and q is the temperature at which the measurements are being made.

As solidification proceeds, the cells will grow. If it is assumed that each cell grows triaxially and that all cells, at all stages of growth, are geometrically similar, then the volume occupied at temperature r by a cell nucleated at temperature q will be

$$K\left[\sum_{r}^{q} G_r \, \Delta t_r\right]^3$$

where Δt_r = time spent at temperature r, K is a constant depending on the shape of the cell ($K = 4\pi/3$ for spherical cells), G_r = the growth of the cell in a specific direction, per unit time, at temperature r.

Hence the change in volume of a eutectic cell during the time interval Δt_r at temperature r is

$$K\left[\left(\sum_{r}^{q} G_r \Delta t_r\right)^3 - \left(\sum_{r-1}^{q} G_r \Delta t_r\right)^3\right] = \Delta V_{r,\,(r-1)}^{q}$$

and the total change in volume, due to all cells nucleated at temperature q, is

$$\Delta N_q \Delta V_r, \overset{q}{(r-1)}$$

However, only that part of this growth which occurs in the liquid results in an increase of the volume of solid. Hence, the true increment is

$$V_r \Delta N_q \Delta V_r, \overset{q}{(r-1)}$$

where V_r is the fraction of the volume which is liquid at temperature r.

The total volume increment, due to all cells, is therefore

$$\sum_{r=r}^{r=o, q=o} V_r \Delta N_q \Delta V_r, \overset{q}{(r-1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

To establish Δt_r, the time supposed to be spent at temperature r, it is assumed that the time spent at a temperature depends on the mass which solidifies at that temperature, and upon the rate of heat abstraction:

$$\Delta t_r = \Delta t_o + K_i(\Delta m_{(r-1)}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where Δt_o is the time spent at a specific temperature, immediately before solidification, K_i is a constant (proportional to the latent heat of solidification) and $\Delta m_{(r-1)}$ is the closest available approximation to the mass solidifying at temperature r.

The smaller the temperature interval, $\Delta\theta$, the less is the error resulting from using this expression.

Expression (1) has been evaluated serially for specific values of the nucleation and growth parameters. Unit change in the value of equation (1) was assumed to correspond to a volume increment of $10^{-5}\%$, whilst K_i was set at 100. The premises and results are shown in Fig. 27. Curves M and N show the hypothetical variation, with temperature, of the nucleation-rate per unit volume of liquid metal for the iron–graphite eutectic in the inoculated and uninoculated states. Curve O applies to the iron–cementite eutectic. Curves P and Q show the hypothetical change, with temperature, in the radial growth-rate of the iron–graphite eutectic for the inoculated and uninoculated states, and R is the growth-curve for the iron–cementite eutectic. Eutectic cells, whether of iron–graphite or iron–cementite, are assumed to be spheroidal. Insertion of the values derived from these curves in equations (1) and (2), gives the temperature ranges over which solidification will occur. These are shown by blocks S, T, and U.

Comparing S and T, it is seen that inoculation raises the temperature of solidification, widens the temperature range over which solidification occurs, and increases the proportion of iron–graphite eutectic, at the expense of the iron–cementite eutectic. Comparing T and U, it is seen that increasing the rate of heat-abstraction lowers the solidification temperature of the inoculated iron and suppresses solidification of the iron–graphite eutectic.

These simple examples, which are supported by practical observation, tend to confirm the validity of the proposed model. The method of calculation is a very powerful one and can be used in other ways. For example, by working backwards with data collected from observations upon castings quenched during solidification, it would be possible to derive the values of N and G, and hence to plot the isothermal-transformation diagram for the eutectic reaction.

CONCLUSIONS

The structures of $2\frac{1}{4}$-in. dia. cast-iron and cast-steel balls which solidified in moulds vibrating at 100 c/s with an amplitude of about 0·050 in. have been studied. The conventional columnar structure of the austenite dendrites in steel and the primary carbides in hyper-eutectic white iron are largely eliminated by vibration. The former are replaced by equiaxed dendrites, the latter by carbide platelets of random orientation.

Magnesium-treated cast iron, which would normally be substantially carbidic, can be graphitized by vibration to give spheroidal graphite, even when the silicon content is less than 0·2% and the metal is cast into a chill mould.

Vibration, during solidification, of a chill-cast En 24-type steel markedly reduced micro-segregation but produced a thin band of macro-segregation some distance from the cast surface. The position of this band varied with the rate of solidification. By casting into a vibrating sand mould instead of a chill mould, the solidification rate was reduced and the segregated band was eliminated.

A theory is proposed to explain the general phenomenon of inoculation in iron castings.

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The new medium-section mill at the Cleveland Works of Dorman Long (Steel) Ltd

By V. Harrison and V. Stephenson

SYNOPSIS

The medium-section mill at the Cleveland Works of Dorman Long (Steel) Ltd, is designed to produce structural sections weighing up to 20 lb/ft at a weekly output of 4 000 tons. There are four mill stands, a 3-high roughing mill of 30-in. centres, two 3-high intermediate mills of 26-in. centres, and a 2-high finishing mill also of 26-in. centres.

A feature of the mill is the continuous flow of bars from the saws to dispatch. The two saws have push-button controlled measuring gear of original design, to keep pace with the mill output, and extensive cooling and sorting banks facilitate the grouping of customers' orders before roller-straightening and direct loading into wagons.

1643

THERE ARE SEVERAL mills in the UK with roll centres 18–23 in. and weekly outputs of about 2 500 tons, producing sections from 5 to 15 lb/ft. The Dorman Long medium-section mill at Cleveland Works with roll centres of 26 in. is designed to produce a range of sections up to 20 lb/ft with an estimated output of 4 000 tons per 17-shift week. With this tonnage in view the finishing department is highly mechanized for rapid sorting and despatch.

The mill has four stands, a 3-high roughing of 30-in. centres, two 3-high intermediate stands of 26-in. centres and a 2-high finishing, also of 26-in. centres. The intermediate and finishing stands are in line across the mill, with two drives, the second intermediate and finishing mills being coupled for drive from one motor. The roughing mill is located some 140 ft ahead of, but off-set from, the first intermediate stand. Transfer to the first intermediate roller gear is by floor skids.

The furnaces are designed to reheat 21-ft long blooms ranging from 6 in. × 6 in. to 8 in. × 8 in. which, for most of the sections, give rolled lengths between 200 and 300 ft. The roller tables at each stand are of ample length, so that the mill floor never limits the length of bar which can be rolled.

The saw track will accommodate bars up to 300 ft long, allowing the use of full-length blooms and giving about 1 ton per bar on 6-in. blooms and 2 tons per bar on 8-in. blooms.

The roll pass layout is for 14, 12, or 10 passes; 14 and 12 pass orders have 7 or 5 passes at roughing, 3 at each intermediate, and one in the finishing rolls; 10 pass orders have 5 passes at roughing, 2 at each intermediate and one in the finishing rolls.

The sections rolled are as follows:

B.S. channels	4 in. × 2 in.	up to 8 in. × 3½ in.
Equal angles	3½ in. × 3½ in.	,, ,, 5 in. × 5 in.
Unequal angles	3½ in. × 3 in.	,, ,, 7 in. × 4 in.
Joists	3 in. × 3 in.	,, ,, 8 in. × 4 in.
	and including 6 in. × 4½ in.	

A corrugated crown-tree section for use with colliery arches is also rolled.

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The authors are with Dorman Long (Steel) Ltd.

The bar-handling equipment is designed to eliminate the use of tongs, bars, and forks in normal working. The roughing-roll designs are arranged so that turning up for edging passes is done at the front side, where a Freimel manipulator is provided. At the back side of the roughing, a bar traversing mechanism is incorporated with the lifting table. Each bar rolled requires only one movement of the traversing mechanism as the early passes are double drafted.

At the two intermediate stands, bottom pass entry is again at the front or furnace side, the lifting tables being at the back or saw side. Manipulation between passes in the same stand is by deflector plate; transfer between stands is by floor skids.

The mill arrangement allows for simultaneous rolling of a bar in each stand, that is, four bars at once in the mill (Fig. 2). The mill is operated by five control drivers manipulating the bars without assistance from the mill crew. There is a control station at each side of the roughing mill, two at the front side of the finishing train, and one operator controlling the two lifting tables and the floor skid on the back side of the intermediate mills. To give operators a clear view of the entry guides, their control pulpits are cantilevered over the mill roller tables. From the finishing rolls bars can be routed through either of two sawing, cooling, and straightening lines.

The two saws are situated 345 ft from the finishing rolls at opposite sides of the twin saw track. This saw track is common for the first 40 ft from the rolls and then divided, each section being controlled from the appropriate saw pulpit. The saws take alternately

TABLE I
Dimensions of new buildings

	Span ft in.	Length ft in.	Height to crane rail ft in.	Cranes
Bloom bay	120 0	349 0	24 2	7 tons
Mill bay	90 0	417 6	36 0	160 15 and 30 tons
Roll shop	40 0	332 0	21 3½	10 tons
Cooling bay	120 0	585 0	24 3	10 tons
Loading bay	86 6	1 129 0	24 2	3 at 10 tons

rolled bars, diversion to the required saw being automatic. Saw measuring is by push-button controlled measuring beam, carrying four stopper heads.

After sawing, the bars are cooled on reciprocating primary cooling banks and are sorted into orders on secondary banks before roller straightening. These cooling and sorting banks necessarily include a high degree of mechanization for the rapid sorting and straightening operations. The two roller-straightening machines feed directly to loading banks ready for immediate despatch.

Mill equipment

Briefly the mill equipment as shown in Fig. 1 consists of :

- Two reheating furnaces, each rated at 45 tons/h
- One 30-in. centre three-high roughing stand with Freimel-type manipulator and lifting table
- Two 26-in. centre three-high intermediate stands with lifting tables
- One 26-in. centre two-high finishing stand
- Two hydraulically operated saws with push-button operated measuring gear
- Two finishing lines, each consisting of:
  - One reciprocating-type primary cooling bank divided into two sections
  - Four sorting banks
  - One 26-in. roller-straightening machine
  - Two loading banks.

Site and buildings

The site chosen for the medium-section mill was made available within the Cleveland Works boundary, when the new Tees Dock Road was built on the east side of the site. The new buildings are listed in Table I.

All these buildings have Mansard roof trusses with the exception of the bloom bay which is an extension of an existing pitched-roof building. The Mansard roof trusses include lighting access walkways and glass-cleaning trolleys for easy cleaning of the inside of the roof glass. General access about the mill is improved by having ground and elevated walkways passing between stanchion legs.

Road access is provided into each mill building from a new works road on the east side, this road starting from a new works entrance near the north end of the mill and joining existing works roads at the south end of the mill.

The existing railways were not adequate to handle the increased rail traffic and modifications and extensions were necessary, which included resiting weighbridges and building a bridge over a spur road connecting with the Tees Dock Road. The exchange sidings to British Railways were also extended.

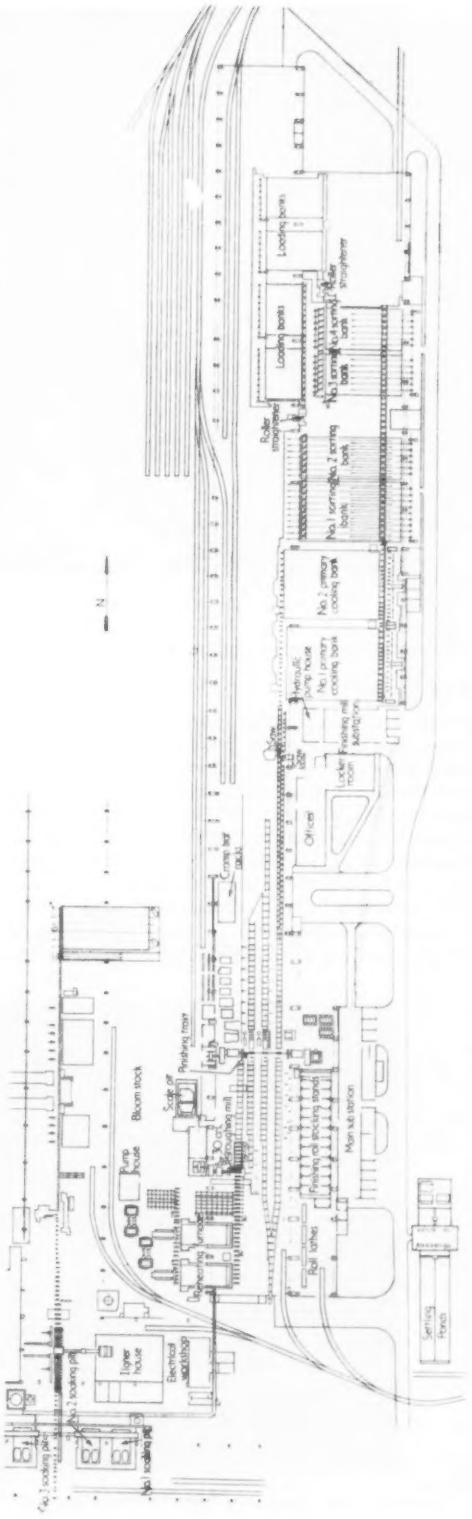


Fig. 1—General layout of medium-section mill

Fig. 2—View of roughing mill with finishing train in the background

ROLLING MILL EQUIPMENT

Reheating furnaces

The two 3-zone reheating furnaces (Fig. 3) are each rated at 45 tons/h, using a mixed blast-furnace and coke-oven gas of calorific value 170 Btu/ft^3. The combustion air is preheated in needle-type recuperators. Each furnace is 53 ft long with a width between side walls of 24 ft allowing a maximum hearth load of 150 tons. The burden is carried on water-cooled skids extending through the heating zone and on a solid brick hearth in the soaking zone.

The main heating zone has 7 top and 5 under burners, the soaking zone 7 end burners. Furnace temperature control is by roof pyrometers regulating the air and gas flow. Air/gas ratio and furnace pressure are also automatically controlled.

The furnaces require 2 500 gal/min of clean water at 40 lb/in^2, normally supplied by an electrically driven pump. In the event of pump failure, a 100-hp diesel stand-by pump is brought into action by a pressure switch in the furnace feed-supply main.

Return water from the furnaces flows by gravity from the tundishes to a hot sump and then is pumped through forced-draught coolers to a cold sump for recirculation, the whole system being separate from the other mill water systems.

A chain feed bank, located in the bloom bay and

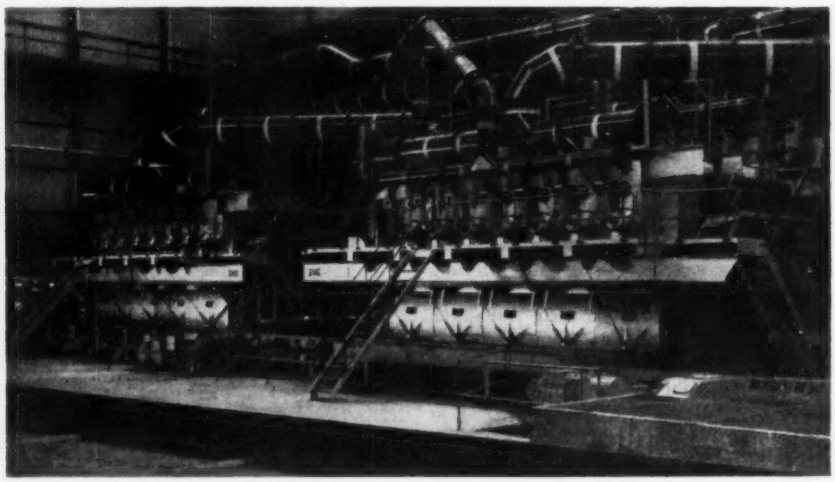


Fig. 3—Discharge end of reheating furnaces

Fig. 4—Front side of roughing mill

loaded by magnet crane, feeds both furnaces. The bank incorporates 4 chains with ducking fingers, which deposit groups of 4 blooms on the furnace feed roller gear.

The furnace hydraulic system works at a pressure up to 3 500 lb/in² which is equivalent to a pusher thrust of 100 tons. Included in the system is a booster pump which provides rapid movement under light load conditions and cuts out at a pressure of 1 500 lb/in².

Roughing mill

The roughing mill approach and working roller tables consist of lineshaft driven rollers of 7 ft barrel length. The Friemel manipulator located 12 ft from the mill centre-line consists of a carriage traversing the front of the mill and mounting one vertical driven bobbin and one inclined bobbin, the inclination of which is adjustable to accommodate varying bloom sizes. Each bobbin has independent vertical movement to achieve turning of the bloom (Fig. 4).

The roughing mill rolls have a 7-ft barrel length; the roll necks are 18-in. dia. and 18-in. long and run in fabric bearings. The screwing adjustment for top and bottom rolls is via ratchet shaft and worm gearing.

The middle roll bottom chock rests solidly on a ledge on the housing. The middle roll top chock is held down by screwed wedges fitted under the housing cap, the distance pieces between chock and housing cap being slabs which also form wearing plates for the top roll bearings. The top roll assembly is held up to the screws by spring-loaded linkage from the housing cap. Roll end adjustment is by means of a tie-bolt between hinged clamps.

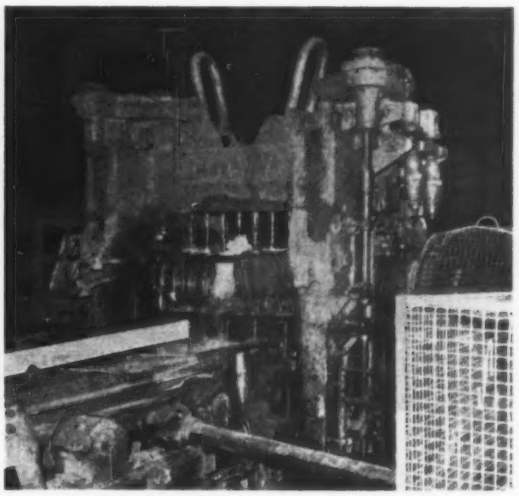


Fig. 5—Back side of roughing mill showing lifting table and bloom traverse gear

The mill is driven by a 2 000/4 000-hp motor on a d.c. supply with variable speed control and inching reversing facilities. The motor speed range is 375–750 rev/min giving a range of roll speeds of 55–110 rev/min, the three-high pinion housing being driven through a reduction gear incorporating a flywheel with the stored energy of $1{\cdot}58 \times 10^6$ ft-lb at 375 rev/min. The mill spindles have universal couplings at the pinion end and wobbler boxes at the roll end.

The electrically operated lifting table on the back side of the mill is 30 ft long and includes a bloom shifting device for traversing the blooms on the table (Fig. 5). The roll design is arranged so that all turning is done on the front side of the mill.

The bloom shifting device has two movements :

(i) Rotation about the centre-line of the shaft to raise or ambush the fingers

(ii) Traversing across the lifting table roller gear, both movements transmitted through a single shaft from separate drives mounted on the floor alongside the table.

The rotary movement which raises and lowers the fingers is through a worm reduction box with crank and connecting rod. The drive for the traverse movement is through spur reduction gear and nut giving lateral displacement of the screw shaft.

Main drive electrics

As mentioned previously the roughing mill has its own main drive motor. The first intermediate mill also has its own motor whilst the second intermediate and finishing mills are coupled to a single motor.

The three main drive motors are identical compound-wound d.c. machines each rated at 2 000/4 000 hp. The supply for the motors is from grid-controlled steel-tank pumpless mercury-arc rectifiers via links on the main control board which can be arranged to give:

(i) Normal working when each motor is fed from its own rectifier, or

(ii) Common working, when in the event of failure of a rectifier all the three motors can be supplied in parallel from the remaining two rectifiers.

Fig. 6—Intermediate and finishing train (looking back towards the roughing mill)

The motors are first brought up to base speed of 375 rev/min by increasing the voltage to maximum by means of the grid control and further speed increases to the selected rolling speed, within the range 375–750 rev/min, is by field weakening. The electronic/magnetic amplifiers which form part of the grid control equipment serve to detect and compensate for any voltage decrease when a bar enters the rolls. The speed range on the first intermediate mill gives a variation in roll speed of 65–130 rev/min whilst the drive to the second intermediate and finishing mills gives a range of 80–160 rev/min which corresponds to a finished bar speed between 550 and 1 100 ft/min.

The responsibility for speed selection on all three main drive motors is in control of the mill operators. The starting-up procedure is that electricians first make alive the rectifiers and close-up the d.c. control supply to the main board in the substation after which control passes to the operators. The main motor cabinet is mounted adjacent to the other mill controls at the control point.

Intermediate and finishing mills

All the three mill housings are similar 26-in. centre 3-high stands incorporating fabric bearings (Fig. 6). In the finishing stand, where there is only a single pass, the top roll serves only to carry the drive across to the top roll in the second intermediate stand.

Each of the two mill drives includes a vertically split pinion housing, half of which, complete with pinions and bearings, can be lifted out as a unit. The driving spindles are supported in spring-mounted carriers and have universal couplings at the pinion ends with wobbler boxes on the roll ends. The universal couplings are enclosed with the pinion housing and lubricated from its oil system.

There is screw adjustment for top and bottom rolls, the top roll assembly being held against the top screws by tie-bolts hung from springs on the housing cap. The middle roll chocks sit on ledges in the housing windows and are held down by screw wedges. Before these wedges are tightened the two middle chocks are shimmed apart to allow a flow of cooling water at the bearing surface.

Bearing life in the mill has been very good and over a period of 15 months no bearings have needed changing in the roughing mill, and only very few have been changed on the intermediate and finishing mills.

The two intermediate mills have electrically operated lifting tables on the back side, each of which has a deflector for moving the bloom across to the next pass. This deflector consists of a hinged plate which is lifted by the bar coming from the mill and drops to form a deflector into the next pass.

Fig. 7—Front side of intermediate mill

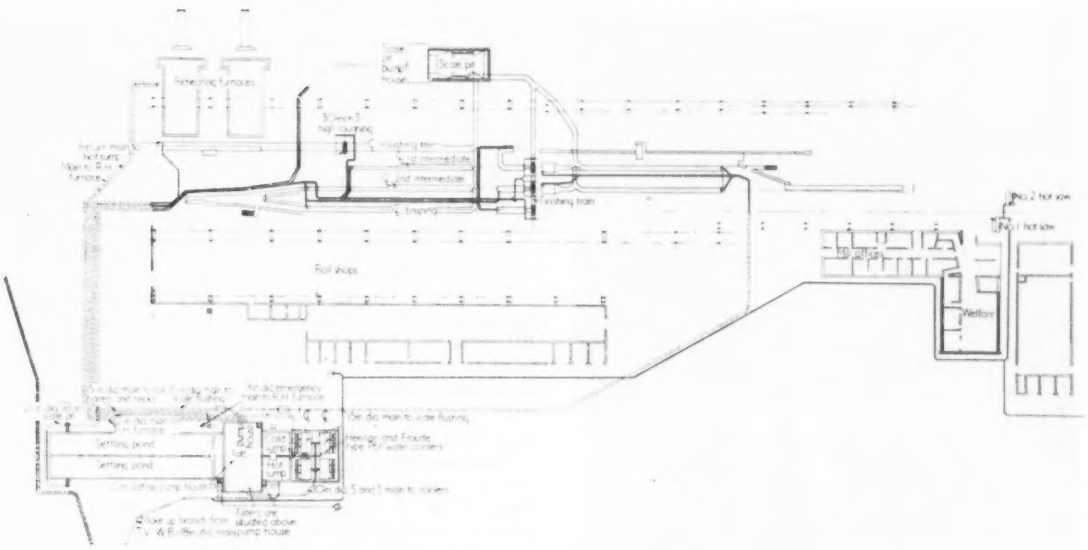


Fig. 8—Layout of water systems

On the front side of the two intermediate mills, the bar emerging from a top pass is carried in a chute over a stationary nosepiece which deflects the bar into the subsequent bottom pass (Fig. 7). These deflectors dispense with man-handling or mechanical skidding between passes at the same rolls.

To facilitate rapid changing, four spare mill housings are provided. The roll change area includes roll stocking racks, guide shop, and guide stocking area and is serviced by a small semi-goliath crane in addition to the mill cranes. The semi-goliath crane allows guide setting to be done without using the main roll-change cranes.

During roll changing each mill housing, complete with rolls and tackle, is lifted from shackles on the housing cap by the 100-ton mill crane and carried into position.

The roller tables on both sides of the intermediate and finishing mills consist of individually driven rollers mounted with variable-speed motors. These motors are a.c. squirrel-cage induction motors fed at low frequency from converters in the main substation. In the case of all roller motors from the second intermediate ingoing to the primary cooling banks, the supply frequency and consequently the speed can be varied within a range to give a roller peripheral speed similar to that of the main stands. This selection is made from the control stations.

A further point of interest is that the motors are of ' floating ' construction, i.e. mounted on the extended roller shaft, the stators being prevented from revolving by means of a flexible tie-bar. This protects the motors against damage when the rollers receive heavy impacts.

On the front side of the mill are two sets of floor skids of the ducking finger type, one set controlled by each of the two front-side operators. On the back side of the mill is a single set of skids for transferring between the first and second intermediate mills. These skids, as all the mill and cooling bank rope skid gear, are driven through fluid couplings by mill-type a.c. slipping induction motors.

Guide tackle

At the roughing mill, for each set of rolls special cast-steel cramp bars are used which incorporate side horns and flat guides for slabbing passes. Top guides are chain-suspended from a balance arm and held down by a short length of billet located in square holes in the side horns. The cramps rest on ledges on the housing and are securely fastened by horizontal and vertical wedges at the housing face.

At the intermediate and finishing stands, the cast-steel side horns are bolted on to plain cramp bars which are standard for all sections. The horns are fastened to the cramp by a tapered lug at the front and a wedge-headed bolt at the back, both fitting matching tapers on the cramp, so that each horn is secured by one bolt. The side horns for delivery are shaped to form stops for the heels of the bottom guides and include holes for securing top guides. In the case of joists where top web and flange guides are required, combination guides are used. The flange guides are pivoted on a spindle passing through the web guide and are made tail-heavy to hold them to the roll.

Water systems (Fig. 8)

(i) Furnace cooling-water system (previously described) is completely separate from the other two systems
(ii) Filtered water system for roll necks and barrels
(iii) Flushing water system.

Roll necks and barrels are supplied with 2 000 gal/min of filtered water at a pressure of 50 lb/in². Pumps draw the water from settling ponds and pass it through four pressure filter units. These units consist of 20 ft-dia. elevated cylindrical tanks, each with a 30-in. thick layer of wood wool. The flow of water is upwards through the filter layer leaving

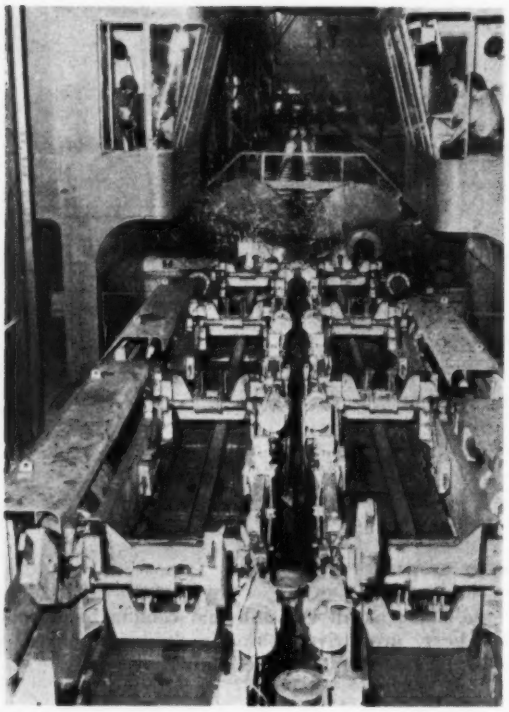


Fig. 9—Hydraulically operated saw measuring gear (looking towards finishing mill)

behind any suspended scale etc. The four tanks mounted above the pump house form a reservoir which, in the event of pump failure, allows time to clear the mill before shutting down. To clean the filter layer the full tank is allowed to drain, giving a reversed flow through the wood wool and removing adhering scale. From the mill stands the water flows along the scale flumes into the scale pit.

Water for scale flushing is taken direct from the settling pond by two pumps delivering 2 500 gal/min at 20 lb/in². The water is delivered to end points in the flumes beneath the mill stands and roller tables and flushes down to the scale pit.

The scale pit is divided into two sections to allow scale settlement. The mill water (which includes neck and barrel water) first discharges into a concrete tank within the scale pit. This tank, some 15 ft square and 9 ft deep, allows water to weir over on three sides, giving a very slow flow of water, allowing scale to settle in the tank, from which it is removed periodically by means of a grab.

The water passing over the weir flows into a deep sump from which it is pumped back to the settling ponds for recirculation, the pumps being controlled by water-level electrode switches.

Hot sawing equipment

The runout from the finishing mill divides into two roller tracks feeding the two saws alternately. An air-operated deflector-switch arm is located at the mill end of the twin roller track. A photo-cell working in conjunction with solenoid-operated air valves, causes the arm to swing over after the tail end of a bar has passed. An over-riding manual control for the deflector switch is provided in the saw pulpits.

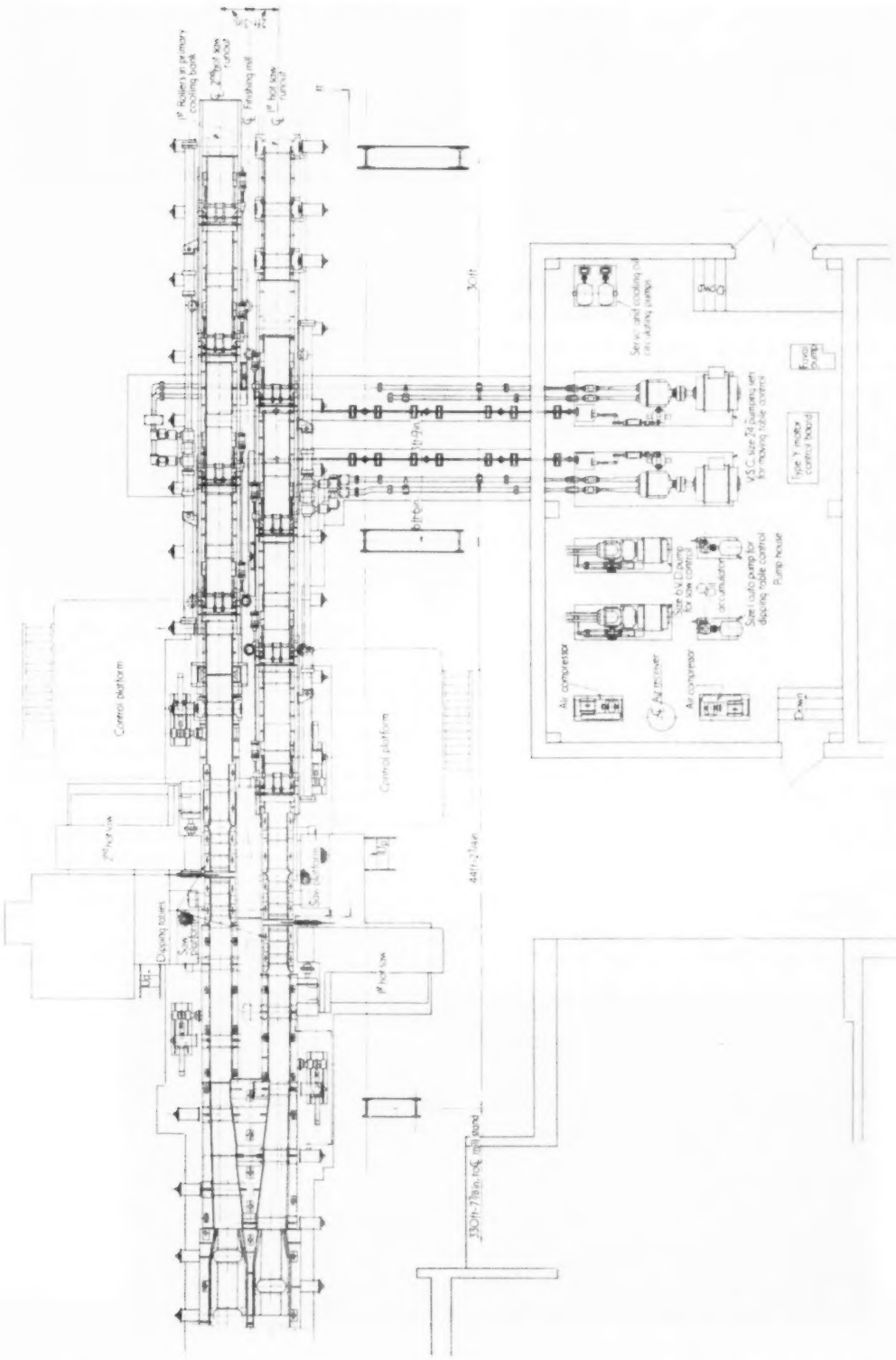
The saws are of inclined sliding type with 54-in. dia. ¼-in. thick blades, with a saw speed of 1 500 rev/min. The saw traverse is hydraulically operated giving a cutting stroke of 5 s. Crop disposal is by hydraulically operated dipping tables discharging into a common chute and crop pit. A hydraulically operated gate holds the crops in the chute while the crop pan is being changed.

Working in conjunction with each saw is a unique hydraulically operated measuring beam, (Figs. 9 and 10) capable of positioning bars for cutting lengths from 10 to 50 ft. Each beam is built from heavy slabs and carries four air-operated stoppers. Traversing is done hydraulically, with two cylinders mounted on each beam, working in conjunction with fixed rams.

The saw measuring-beam arrangement gives push-button selection of stopper position for every inch from 10 ft to 49 ft 11 in. with adjustable variations of contraction allowance between 1 in. and 2 in. per 10 ft. The beam and beam movement are graduated to include the average contraction allowance of 1½ in. per 10 ft 0 in. In the following description, all dimensions have been reduced to the equivalent cold bar condition, i.e. a dimension stated as 10 ft 0 in. is actually 10 ft 1½ in.

The beam carries four stoppers spaced at 10 ft 0 in. and has a total movement of 9 ft 11 in. so that stopper selection gives the tens of feet and the remaining feet and inches are obtained by a selection of the beam position. The first stopper with zero beam movement is 10·0 ft from the saw blade. Oil hydraulic power is supplied by variable-delivery pumps, located in a separate pump house (Fig. 11). Direction, rate of oil flow, and hence beam movement depend on the inclination of the tilting block or swash plate in these pumps. Three factors, working through differential gears, control a screw-and-link mechanism which, powered by a servo ram, gives the required inclination in the pump. These factors are, first, a pilot motor of which the revolutions correspond to the pre-selected beam movement required; second, an auxiliary pilot motor of which the revolutions correspond to the contraction allowance adjustment over or under the average; third, the actual beam movement which is measured off through a pinion driven by a rack on the beam itself. Thus, movement on the pilot motor through the differential box causes tilting block inclination in the variable delivery pump, which moves the beam. This beam movement through the rack and pinion cancels out the movement of the differential box so that when the pilot motor stops, the inclination in the pump returns to zero and the beam stops. Hence, the beam position is controlled by the pilot motor. Incorporated with the positional control is a speed control, the beam having three speeds, top speed 40 in./s, medium speed 16 in./s, and 'creep'. Length selection is by push button, operating through two rotating contact units which control the pilot motor.

When the beam is in the correct position, the selected stopper is dropped and once the stopper is


Control platform
Control platform
Control platform
Air compressor
Air compressor
Pump house
Type 'T' motor control board
Finish pump
Delivery tables
Saw pit
Saw pit
Saw pit

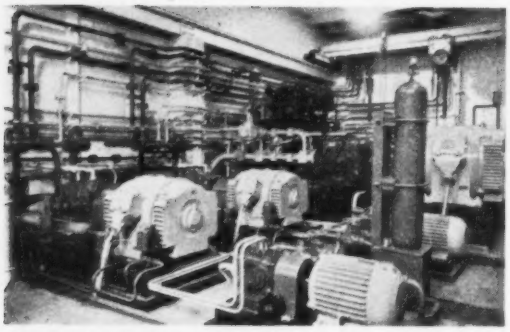


Fig. 11—Hydraulic pump house for saw measuring gear

down the selection is locked. The sawman is then free to select his next required length on the push-button desk, while the driver runs the bar up to the stopper and makes the cut. Lifting of the stopper cancels the former selection and the beam immediately moves to the new selection.

Each sawman is located in a separate pulpit positioned on either side of the measuring beams and works at a desk containing the push buttons for beam positioning. Working in conjunction with the sawman is the saw driver who has controls for incoming and outgoing roller gear, dipping crop tables, saw stroke, and stoppers.

The sequence of operations is as follows: the saw driver runs the bar up to the saws, saws off the crop, and disposes of it by the dipping table. Meanwhile, the sawman selects the cutting length on the push buttons and as the stoppers are all in the 'up' position, the beam moves to the selected length. The driver then operates the stopper 'down' switch and the selected stopper drops. The selection is now locked and the sawman is free to select his next length on the push buttons. The driver now operates the saw and on completion of the cut, he operates the saw return switch which also raises the stopper. As the stopper lifts, it operates a relay to release the selection locking relays and immediately the new selection takes effect.

Finishing department

The main feature of the finishing department is the continuous flow of the bars from the saws to despatch,

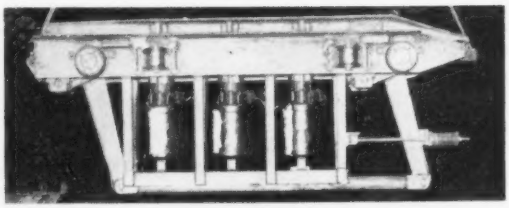


Fig. 13—Thrustor-operated skid carriage for primary cooling bed

through the stages of cooling, grouping into complete orders, and straightening.

The flow of bars from the two saws proceed on separate routes, as follows:

No. 1 Saw	No. 2 Saw
No. 1 Primary cooling bank	No. 2 Primary cooling bank
No. 1 and 2 sorting banks	No. 3 and 4 sorting banks
No. 1 Roller straightener	No. 2 Roller straightener
No. 1 and 1*a* Loading banks	No. 2 and 2*a* Loading banks

Before proceeding with the description of the plant the system of working should be explained. The emphasis is now on the completion and despatch of customers' orders and the sorting banks are used to ensure that the bars reach the straightening machines in complete orders to facilitate quick loading. The stocktaking system depends on the coding of customers' orders, that is, before the start of a rolling all the orders are sorted and the sheets marked with code numbers for easy identification, thus the sawman, hot bank stocktaker, straightening machine stocktaker, and loading stocktaker each have copies of the coded order sheets. The sawman cuts one main code using one or two other codes as savers to ensure minimum cutting of scrap at the back end of a bar. The sawman and hot bank stocktaker have previously discussed their cutting programme, so the stocktaker recognizes the bars as they come to him and marks each bar with its code number. Savers are indicated by a signal over an intercommunication loudspeaker system and various messages such as, 'Completion of order' are given over this system by the sawman. Normally, the operator pushing the bars off the saw roller gear on to the primary bank, feeds the two halves of the bank alternately while on the main

Fig. 12—General view of primary cooling beds

Fig. 14—Thrustor skid carriages at cold side of primary cooling bed

code, and puts all bars of the saving codes on one half of the bank only. Thus, when the bars reach the take-off end of the primary bank, any two bars in line are of the same main code, whereas single bars are savers.

The operator on the thrustor carriages taking bars off the primary bank takes them in groups according to code numbers so that any group on the roller gear between primary and sorting banks contains bars

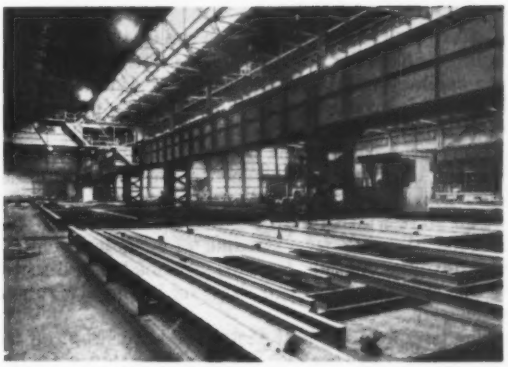


Fig. 16—Loading banks

of one code only. As the groups run down the roller gear, instructions are sent by electrical indicator panel to the sorting bank operator who skids the bars on to the appropriate sorting bank. Thus main code orders are pushed down the main sorting banks and saving orders on to the secondary banks. When the last bars of a saving order arrive at the sorting banks they are skidded off on to a main sorting bank and the bars of the same code on the secondary bank are transferred across the roller gear to join them. By this system, bars of one code all follow through the roller straightener and go on to one loading bank. The machine stocktaker checks the bars coming through the machine according to the codes, and paints on them the length and other customers' marks, and the bars are made into slings and so complete loads are made up and despatched without delay. The twin loading banks can be used for additional sorting, but normally one bank is used at a time, that is, loading from one, while the other is being filled.

The description of the plant in the finishing department follows.

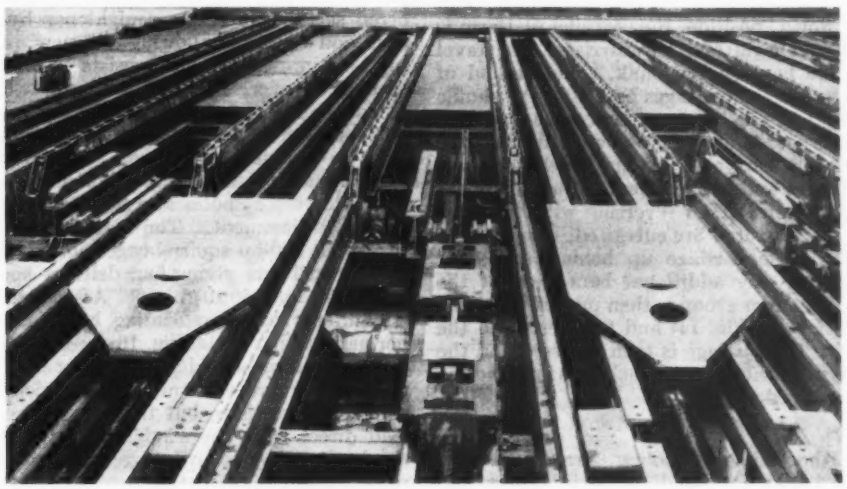


Fig. 15—Transfer equipment in sorting banks showing solenoid and thrustor skid carriages and chain conveyor

Primary cooling bank

After being sawn, the bars are run on to the primary cooling banks (Fig. 12). Normally, each saw feeds its own cooling bank, but the knock-off skid gear on the first bank is arranged so that it is possible to feed bars to this bank from either saw.

Each primary bank is 90 ft wide with a distance of about 115 ft between the centres of the saw runout roller gear and the cold side roller gear.

The 90 ft width of each bank is divided into two sections allowing two streams of 40-ft long bars to pass down each bank, the two streams being directed by disappearing and dead stops set in the saw runout roller gear.

The bars for each half cooling bed are swept off the saw runout roller gear by skids, a separate set feeding each half bank. These skids consist of wheel-mounted carriages with solenoid-operated fingers for clearing the roller gear and ducking fingers for transferring to the shuffle bars. The shuffle bars, which cover the whole 90 ft bank width on a single drive, consist of a series of ducking fingers mounted in reciprocating beams. The fingers extend from the hot-side roller gear to a line 18 ft from the cold-side roller gear, thus allowing an area for grouping bars before placing them on the roller gear. The shuffle bars are supported on steel balls running in grooved baseplates, and the drive through shafts and levers gives a reciprocating stroke of 21 in.

As previously stated, the cut bars have to be kept in their order group and this raises the problem of taking bars off the bank at the cold side while bars are being put on the bank at the hot side. The method of taking off bars has to be such that movement of the shuffle bars will not affect the grouping of bars on the cold-side roller gear, hence a normal ducking finger skid would not be practical, and also it is difficult to handle cambered bars with this type of skid. These difficulties have been overcome by using a skid gear incorporating a lifting feature.

Thrustors are incorporated in the skid carriage, the wheel-mounted frame carries three 650-lb thrustors which lift and lower the carrying platform (Fig. 13). In the 'down' position, the carrying platform is below bench rail level and the carriage can travel underneath the bars on the bank. The method of operation is to run the carriages back into the shuffle bar area, stopping the carriages beneath a group of bars. The thrustors are then energized and the platform lifts the bars clear of the bench rails and shuffle bar fingers and carries them to the area clear of shuffle bar fingers. After reversing with the platform down, the thrustors are energized, bringing the pushing end of the carriage up behind the order group and lifting any additional bars clear of the bench rails. The order group is then pushed on to the cold-side roller gear (Fig. 14) and transferred to the sorting banks. The carriage is then reversed and the odd bar or bars returned to the bench rails for handling with the correct order group.

Sorting banks

Following the primary cooling banks are four main sorting banks for handling main orders and four small secondary banks for holding saving lengths. A group of bars from any of the four sections of primary cooling banks may be fed to any of these sorting banks. No. 1 primary cooling bank normally feeds nos. 1 and 2 sorting banks, while no. 2 primary cooling bank feeds nos. 3 and 4 sorting banks. As mentioned previously, each main sorting bank has a small secondary bank on the opposite side of the roller gear which serves as a holding area for saving lengths, holding these savers until their order is complete at which time they are transferred across the roller gear, joining the main flow of bars to the roller straighteners.

Groups of bars are transferred to the sorting banks by skid carriages having two solenoid-operated fingers, the distance between fingers being somewhat greater than the length of the roller barrels. The carriage is then driven to a position on the sorting banks, at which point the operator puts his control to neutral which automatically drops the finger and returns the carriage to its ambush position in the roller gear. This procedure is repeated when placing bars on the secondary banks, the controller being reversed and position 2 on the selection switch being engaged. When transferring bars from the secondary banks to the main sorting banks, position 3 is selected which allows the carriage to pass under the bars on the secondary bank. The carriage is then reversed which raises the correct finger behind the bars and transfers them across to the main bank.

Working in conjunction with the solenoid skids are thrustor-type lifting carriage skids of a similar design to those used on the primary cooling banks and whose function is to carry the bars deposited by the solenoid skids and place them on a slow moving-chain conveyor feeding the roller straighteners (Fig. 15).

Roller straightening and despatch

The chain conveyor of each pair of sorting banks discharges on to skewed roller gear feeding a 26-in. roller-straightening machine. On the front of each straightener is a feeder for assisting vertically cambered sections into the straightener by forcing the front end down and allowing it to pass under the first top bobbin. This feeder consists of a small inclined apron conveyor, the inclination of which can be adjusted to accommodate variation in camber. The roller straighteners are 26-in. centre machines using built-up bobbins with three top and four bottom spindles, all of which have horizontal adjustment. The three top spindles also have separate motorized vertical adjustment. The machines are driven by two-speed 150-hp squirrel-cage motors, through two-speed gear boxes giving four delivery speeds ranging from 180 to 350 ft/min. Associated with each straightener are two loading banks equipped with normal ducking skids (Fig. 16).

There is some stocking ground for finished make as required for orders awaiting inspection or awaiting shipment directions, but the normal procedure is to load direct from the straightening machines. Thus the loading bay is an integral part of the mill and rapid handling is essential.

Comments on the OLP process

By B. Trentini, P. Vayssière, and M. Allard

SYNOPSIS

Following logically from systematic studies pursued by IRSID for several years in the field of lime blowing, the O L P (oxygen–lime powder) process has been developed on an industrial scale. Applied to basic Bessemer pig irons this process results in a very easy dephosphorization in the presence of carbon and, under good economic conditions, in the production of a steel very low in impurities such as P, S, and N. 1711

OUTLINE OF THE O L P PROCESS

THE RAPID INCREASE in the use of pure oxygen in steelmaking furnaces appears as one of the most striking features of the evolution of steelmaking processes in recent years, As literature on the subject has been reviewed very recently by several authors, it is unnecessary to describe again here the different processes and techniques of blowing pure oxygen.

The O L P process (oxygen–lime powder) of refining hot metal by means of lime powder in suspension in a stream of pure oxygen has also been described in several publications since October, 1957,* and it is not necessary to repeat the details of this process, which is a logical development of the systematic studies† that IRSID has pursued for several years in the field of blowing finely divided materials into liquid baths, which led to processes such as the desulphurization of hot metal by lime powder, and the blowing of lime and iron-ore powders through the bottom of basic Bessemer converters.

The technical details of the O L P process have already been published; in this paper only the general features and some of the interesting metallurgical aspects of the process will be mentioned.

To date, 30-ton tests have been made on one of the normal basic Bessemer converters at the Denain steelworks. The usual bottom with tuyeres was simply replaced by a tight bottom, and because of its nose shape the converter had to be leant forward to introduce the water-cooled lance. In these operating conditions the lance axis was appreciably away from the bath centre, the distance from the lining being respectively one-third and two-thirds of the diameter at bath level (Fig. 1).

Oxygen of commercial purity (99·5%) is used in the present local conditions under a pressure of around 90 lb/in² at the bottom of the lime powder dispensers. Lime is crushed by a high-speed hammer mill giving a product with a grain size of 100% under 6 mesh and 50% under 65 mesh (Tyler). Lime coming from the normal bins of the basic Bessemer plant has an average percentage composition of:

CaO	SiO_2	Fire loss	S
85·0	3·0	10·0	0·12

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It should be pointed out that with the O L P process lime of very different compositions and physical aspects can be used without difficulty. Indeed, variation of the 'reactivity' of lime, a rather vague criterion linked in a general way to the rock compacity, its burning, size, and surface aspect, is often the cause of trouble during refining processes using pure oxygen. This drawback does not exist with the O L P process because (*a*) of the extremely fine form in which the lime is used, and (*b*) blowing it in an oxygen stream gives a remarkable reactivity whatever the nature and composition of the lime.

The extreme reactivity of lime and the ease of regulation of concentration in the oxygen stream make possible the control of the chemical and thermal evolutions of the bath during refining, and allows the process to be fitted to hot-metal compositions varying in a wide range from hematite high-silicon pig iron to high-phosphorus pig iron.

TECHNIQUE FOR HIGH-PHOSPHORUS HOT METAL

For basic Bessemer hot metal, the refining technique is based on the following principles:

(i) Blowing of powdered lime with oxygen from the beginning to the end of the refining period
(ii) Adaptation of the lime concentration to hot-metal composition, phase of refining, and steel grade to be produced
(iii) Removal of one or two intermediate slags, rich in lime and poor in iron, which takes away an important part of the phosphorus and sulphur brought in by hot metal.

* M. ALLARD and B. TRENTINI: paper presented to the Commission des Ingénieurs d'Aciérie Thomas, Paris, 25th October, 1957; *Rev. Mét.*, 1958, vol. 55, pp. 67–74, 1195–1208; *J. Met.*, 1958, vol. 10. pp. 466–471; *Rev. Univ. Min.*, 1958, vol. 14, pp. 494–500.

† B. TRENTINI, L. WAHL, and M. ALLARD: *Rev. Mét.*, 1956, vol. 53, pp. 388–389; *JISI*, 1956, vol. 183, pp. 124–134; *J. Met.*, 1957, vol. 9, pp. 1133–1139; B. TRENTINI *et al.*: *Rev. Mét.*, 1957, vol. 54, pp. 147–158.

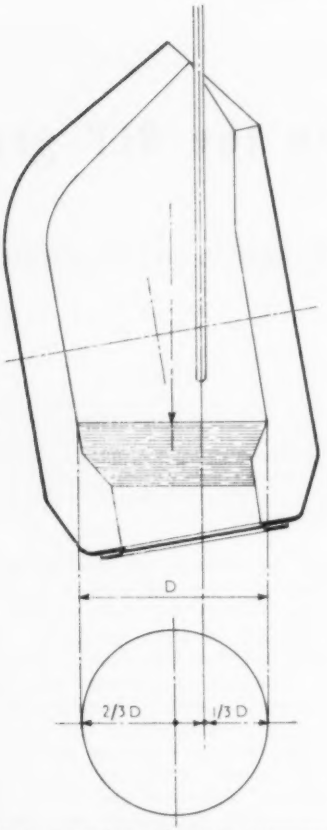

Fig. 1—Location of lance in converter

No addition of lime is made before the start of refining, the only lime in the converter being that from the lime dam of the preceding heat. Likewise no fluxing agent (spar, bauxite) is added. The cooling addition then made can be either scrap or iron ore.

After tilting the converter, the lance is lowered to the required distance above the bath and oxygen with lime powder is blown from the beginning. In the case of the operating technique with only one intermediate slag-off, about 1 800 ft³ of oxygen per ton of hot metal is blown during the first phase, with a corresponding quantity of lime of 240 lb/ton, lime dam included. At the end of that first phase the metal bath contains about 0·6%C and 0·2%P for a temperature of about 1 600° C. The corresponding slag is partially slagged off.

After addition of scrap or ore, depending upon temperature, the lance is lowered and blowing of lime powder and oxygen is resumed until the desired carbon content is obtained. This final blowing time is determined from the carbon analysis of the sample taken at slag-off, and from corresponding (% C/ft³ oxygen) curves. In the case of low-carbon steel, for the second and last phase about 500 ft³ of oxygen and 70 lb lime per ton of pig iron are supplied. Owing to present local conditions the final slag can be recovered only partially for the following charge, with the help of a lime dam made just before tapping.

Figure 2 shows an example of the refining of a 30-ton bath of basic Bessemer pig iron, for which chemical evolutions (C, P, S) and thermal evolution are plotted as a function of the consumption of gaseous oxygen. This example shows the ease of dephosphorization even in presence of carbon, also the important desulphurization obtained during refining.

More generally, steels obtained by the O L P process are characterized by their low contents in phosphorus, sulphur, and nitrogen. Starting from a basic Bessemer hot metal with 1·8%P and 0·050%S, a low-carbon steel with $< 0{\cdot}020\%$P, $< 0{\cdot}020\%$S, and $< 0{\cdot}002\%N_2$ is obtained regularly and without difficulty.

FACTORS CONTROLLING IMPURITIES IN FINAL STEEL

Nitrogen

It is known that the final nitrogen content in oxygen-refined steel depends particularly on the purity of oxygen blown. In the present case, only one oxygen grade of 99·5% purity was used, and under these conditions the nitrogen content in metal bath at the end of blowing was systematically very low: 0·001–0·002%.

Three remarks can be made on this point:

(i) No influence of temperature was found

(ii) With such a low nitrogen content at the end of the blow there was some risk that an appreciable pickup of nitrogen would occur during tapping, when the metal stream came into contact with air. Accurate sampling and repeated analyses have shown that this is not so: nitrogen pickup during tapping is very low, of the order of 0·0003%.

(iii) In literature there is mention of strong nitrogen pickup when intermediate tilting down is made in an oxygen top-blown vessel, this increase in nitrogen of the order of 0·004–0·005% being due to air entering the vessel. All the charges made at Denain have been tilted down at least once for slag-off, but no appreciable pickup of nitrogen was experienced.

Evolution of slag composition

In any steelmaking process, slag composition is of primary importance for final steel quality and this is still more the case when, from a hot metal rich in impurities, steel with very low impurity content is required.

It appears that the refining of hot metal in a dolomite-lined converter, and without fluxing agents

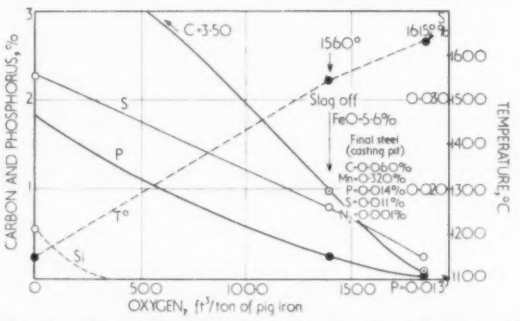

Fig. 2—Chemical evolution (C, P, S) and thermal evolution plotted as a function of the consumption of gaseous oxygen, 30-ton heat, no. 189

such as spar or bauxite has the advantage, compared with usual O H practice, of producing less complex slags. But even in the case of these more simple slags it seems that one of the best ways of studying the influence on slag composition is to use ternary diagrams. Figure 3 is a typical diagram in which the wt-% of $(CaO + MgO)$, $(SiO_2 + P_2O_5)$, and $(FeO + MnO)$ has been plotted to show the evolution of slag during the refining of a basic Bessemer hot metal. The approximate positions of the curves for saturation with lime and calcium tetraphosphate have been drawn, also the miscibility gap for 5% silica.

Zone I corresponds to slag obtained at the first tilting down, when carbon content in bath is 0·6–1% and temperature around 1 600° C.

The slag has the following characteristics:

(i) Very low in iron oxide: after deducting the MnO content (3–5%), there is only 5%FeO for about 1%C, and 9·0%FeO for about 0·6%C
(ii) Very rich in CaO: more than 50% and often more than 55%, so its dephosphorization potential is high
(iii) Poor in MgO: only 1% with a dolomite lining
(iv) Rich in P_2O_5: after deducting the SiO_2 content (6–10%) one obtains P_2O_5 of the order of 24%.

At the end of the first phase, the quantity of such a slag is of the order of 325 lb/ton of basic Bessemer hot metal. Consequently it is necessary to add lime and to dissolve it quickly (about 20 min for the first phase).

In the O L P process this operation of quickly dissolving a large quantity of lime is made without fluxes, because lime is added progressively and in a very reactive form, being finely divided and carried by oxygen itself.

On the contrary, to dissolve such a large quantity of lime when it is brought in by usual means, i.e. in lumps, fluxes are needed or great quantities of iron oxide must be formed by increasing the distance between lance and bath. This last solution is not without drawbacks from the point of view of foaming, lining wear, and oxygen consumption.

Moreover, it seems that with this last technique it is not possible to reach iron oxide contents in intermediate slags as low as in zone I. This tendency is

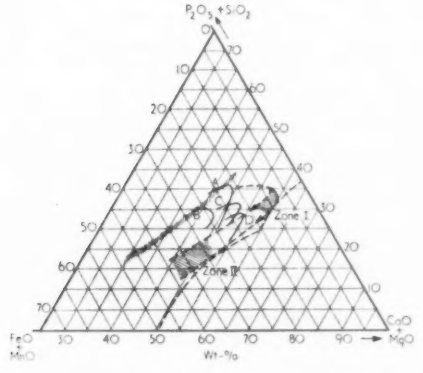

Fig. 3—Ternary diagram to show evolution of slag during refining of basic Bessemer hot metal

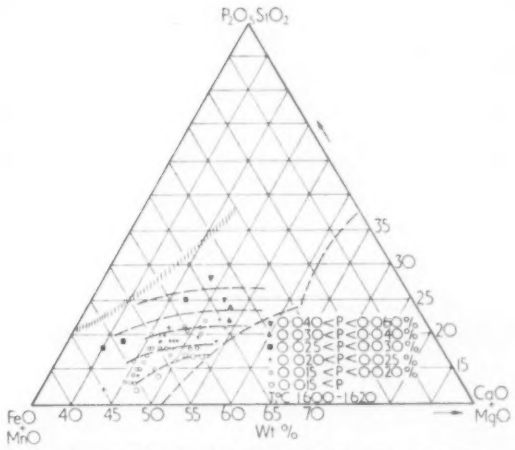

Fig. 4—As Fig. 3, showing phosphorus contents

shown by comparison of the curves *A*, *B*, *C*, *D* in Fig. 3, obtained by jets of pure oxygen alone, in LD tests on high-phosphorus pig iron.

In a series of new experiments (to be published) it will be shown by blowing in the O H lime powder with pure oxygen, lower iron oxide in intermediate slags could be obtained than with blowing only pure oxygen.

Zone II in Fig. 3 refers to final slag corresponding to extra-low carbon steels. This slag is:

(i) Rich in iron oxide, about 30%
(ii) Lower than the first slag in P_2O_5 and SiO_2, because of slagging off and dilution effect
(iii) Still rich in CaO, 45–50%.

During the second and last phase, one has still to dissolve a quantity of lime in a short time (about 6 min at present). The flexibility of lime additions in the O L P process again is an interesting feature, assuring the final basicity necessary for production of low-phosphorus and low-sulphur steel.

Phosphorus problem

At the end of the first phase there is no difficulty in obtaining a slag rich in P_2O_5 (22–26%), leaving only 0·2–0·3%P in the metal bath for a corresponding carbon content 0·6–1%. This slag, rich in P_2O_5, with about 8%SiO_2 and without fluoride has a very high citric solubility and is an excellent fertilizer. Partial removal of it takes away from the total system (slag + metal) an important part of the phosphorus initially brought in by the hot-metal charge.

As far as final phosphorus in steel is concerned, and considering only low-carbon grades, the two well known factors of temperature and basicity of final slag are extremely important. By considering a series of slags whose composition lies in the same range it is easy to show the temperature dependence of the final phosphorus in steel, the lower values corresponding to the lower temperatures. For example, for a given slag composition, values of 0·018%P are obtained at a temperature of 1 600° C whereas with that same slag composition, a temperature of 1 680° C leads to phosphorus contents of 0·028%.

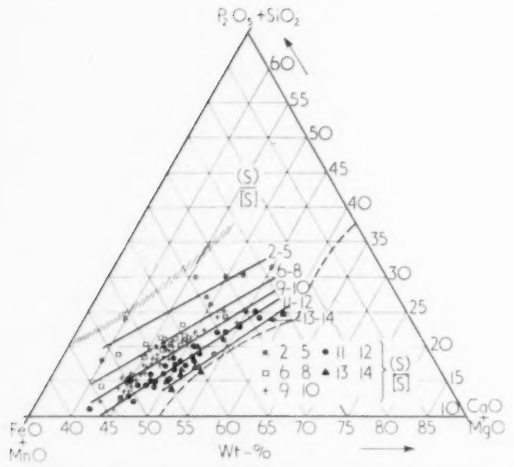

Fig. 5—As Fig. 3, showing equal sulphur partition coefficients

In the O L P process it is easy to maintain the final temperature in a small range around the required value. This is a great advantage of the intermediate tilting-down necessary for slagging off. By measuring the temperature at the moment and knowing the corresponding carbon content, the quantity of cooling additions (light scrap or preferably iron ore) to be added can be deduced from predetermined curves, and practice proves that a final scatter of less than 20° C in final temperature can be obtained.

However, it seems that the importance of slag basicity is even greater than the one of final temperature. On Fig. 4 we have grouped a series of final slag compositions for temperatures between 1 600° and 1 620° C, and for low-carbon steels. The different zones from high to low phosphorus are apparent. If heats with the same FeO content are considered, those with low phosphorus lie along the lime saturation curve. The amount of FeO in the slag corresponds to the lower oxygen content of the steel.

Moving away from the lime saturation curve, basicity increases and oxygen increases, but this increase in oxygen is not sufficient to compensate for the increase in activity of P_2O_5 and increase in phosphorus.

Considerations of equilibrium, and thermodynamic calculations will be developed on that point, but the preceding examples clearly show the advantages to be obtained from the control of temperature and slag basicity, made easy by blowing lime powder in an oxygen stream.

Sulphur problem

Sulphur balance—A study of sulphur balance during the first phase (i.e. from pig iron down to 0·6–1·0%C and 0·2–0·3%P) has shown on a group of 45 heats that at the end of the first phase there is less sulphur present in metal and slag that was brought in by iron and lime during that corresponding period.

If we call:

ΣS_0 the total quantity of sulphur brought in during the first phase

ΣS_1 the total quantity of sulphur present at the end of first phase

we obtain a relative loss:

$$\frac{\Sigma S_0 - \Sigma S_1}{\Sigma S_0} \text{ between } 10\% \text{ and } 15\%$$

Although one must always be cautious about sulphur balance, it seems that this difference is not due to inaccuracy. This sulphur loss can be explained by direct oxidation of slag in the vicinity of the oxygen jet, according to the following reaction:

$$\tfrac{1}{2}\,O_2\,(g) + (S^{--}) \rightarrow \tfrac{1}{2}S_2\,(g) + (O^{--})$$

where S^{--} and O^{--} refer to sulphur and oxygen ions in slag.

Fume analysis has confirmed the presence of sulphur components, but their relative amount was too small to be determined by normal analysis. In these data, no influence could be detected of factors such as oxygen flow, lime concentration, and distance between lance nozzle and bath level. Moreover, because of the impossibility of knowing accurately the amount of slag removed before the second phase, no sulphur balance has been made for that phase.

It should also be noted that for the bottom-blown basic Bessemer converter, other workers agree in general on the statement that there is no sulphur loss during the blow, but in such a case conditions of slag formation and of its oxidation are quite different.

Partition coefficient for sulphur—It has been checked by analysis of numerous O L P samples of slag and metal that the partition coefficients for sulphur (S)/[S] could vary appreciably, for example from 2 to 14, in both intermediate and final samples. To show quantitatively the importance of the partition coefficients upon the final sulphur in steel it can be said that, starting from a pig iron with 0·050%S there will be a sulphur content of 0·033% in the final steel when both (intermediate and final) coefficient partitions are only 4, and 0·017% when these coefficients are 10. Trials to study the sulphur coefficient partitions as a function of excess base ΣMo have given no satisfactory result.

We have represented the lines of equal partition coefficient (S)/[S] on a ternary diagram (Fig. 4) similar to that previously mentioned. For intermediate samples it would be better to consider sulphur activity instead of sulphur concentration in steel because of the high carbon contents (0·6–1·0%) but this would not change appreciably the respective positions of points. Because of very low carbon contents this is not necessary for final samples.

Figure 5 clearly shows how much the sulphur coefficient partition depends on slag basicity, and mainly CaO content.

Moreover, slag composition alone, as shown on the ternary diagram previously considered, is sufficient to determine sulphur partition between metal and slag, at least for final slags. Thus the authors believe that S contents of metal and slag are very close to equilibrium at the end of the blow, and thermodynamic calculations will be developed on that point. For intermediate slags, the problem appears more complex and complementary data are necessary before drawing conclusions.

CONCLUSIONS

In this paper it was intended to show by precise examples how much the quality of final oxygen-blown steel depended upon control of temperature and slag formation.

The blowing of lime powder in an oxygen stream in the O L P process appears as a rational method of achieving this aim with great regularity.

On series of 30-ton heats, the O L P process has also been applied to hematite pig irons with very satisfactory results.

In the UK steelmaking industry, semi-phosphorus iron with about 0·7%P for a long time has been refined only by the O H process, using ore additions. The great flexibility of the O L P process makes it easy to apply to that type of semi-phosphorus iron, permitting regular and economic production of high-quality steels, low in phosphorus, sulphur, and nitrogen.

The development and present state of the LD process

By O. Cuscoleca and K. Rösner

SYNOPSIS

The history of the LD (Linz–Donawitz) process of oxygen top-blowing at the pioneer Austrian plants is briefly surveyed. Vessel linings are discussed and details of steels produced by the process are given. Experience of the LD process outside Austria supports the authors' findings. The process has been adapted to use lime-powder injection in the oxygen jet to reduce the final phosphorus content of the steel. Development of the process is continuing, and it is estimated that 20 million tons of the world's steel will soon be produced annually by the LD process. 1721

IT IS NEARY 11 years since pilot operations were started at Linz and Donawitz with the aim of converting pig iron into steel by top-blowing with commercially pure oxygen. Before this, laboratory experiments and investigations had been carried out by Durrer[1] in 1947. For more than four years the pilot plants were operating with heats of 3–15 tons.[2] The results of several thousand heats were promising enough to justify the erection of the first large-scale production units, which in turn involved the development of many details such as materials flow, operating sequences, arrangement of buildings, and mechanical features, e.g. converting vessels, lances, and controls. After a comparatively short construction time of 2 years, the first two large-scale plants operating on the principles of the LD process started production at the turn of 1952–1953. After more than 6 years running it is safe to state that their layout as well as their mechanical and electrical equipment have given excellent service. Thus a novel type of steelplant has been created, which, except for minor modifications due to local conditions, can be considered as generally tried.

Figures 1 and 2 show the basic arrangement of the existing LD shops complete with mixer and two LD vessels. The Donawitz type (Fig. 1) has the converters located in a central bay, served by the charging bay on one side and by the casting bay on the other. Transfer of pig iron and other charging materials is either by crane or by charging car operating in the charging bay, while pouring and mould preparation is in the separate casting bay.

In the Linz type (Fig.2) the charging bay is flanked by the converter bay and the casting bay. So far the two Austrian LD plants have produced about 5·2 million tons of LD steel.

The Donawitz pilot operations, while chiefly concerned with the production of low-carbon steels and commercial grades, were planned so as to study the suitability of the LD process for the production of higher carbon steels. This had to be done with a view to the highly varied production programme of Alpine-Montan which, with the exception of sheets and seamless tubes, includes all kinds and qualities of rolled products and low-alloy steels.

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Dr Cuscoleca is technical director of the Alpine-Montangesellschaft, Vienna and Leoben, and Mr Rösner is superintendent of the company's steelplant at Donawitz.

Plant and equipment

The first LD shops were equipped with vessels rated for a charging capacity of 25 and 30 tons respectively, the volumes being 28 and 32 m³. Later, however, it became obvious that under conditions of LD steelmaking a vessel volume of about 30 m³ could be made to hold charge weights of up to 36 tons. The two LD shops did not take long to establish characteristic operating data that are valid even today; 54–56 m³ of oxygen per ton of steel (0·7 kWh/m³ oxygen); tap-to-tap time 36 min, with oxygen on for 18 min, which yields 55 tons/h. Based on tap-to-tap time the time taken is nearly 66 s/ton of steel, whilst it is about 33 s/ton of steel if based on blowing time (valid for the production of mild steel only).

It took a little longer, however, to find out the best shape of tuyere and its adjustment, which had a distinct bearing on lance life. It should be mentioned here that at Donawitz, lance life averages 1 000 heats and more, and a standby lance serves for quick replacement. While lance cost is hardly felt in this way, off-heats caused by lance breakdown are practically unknown. The life of a lance certainly depends on the blowing time as well as on the type of operation chosen, not to forget the design and cooling system of the lance.

In the early days of operation, trouble was encountered with the refractory lining owing to the extremely high temperatures developing in the bath zone

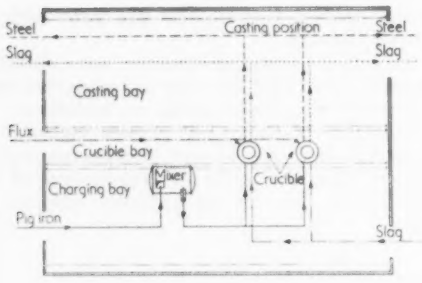

Fig. 1—Donawitz LD shop

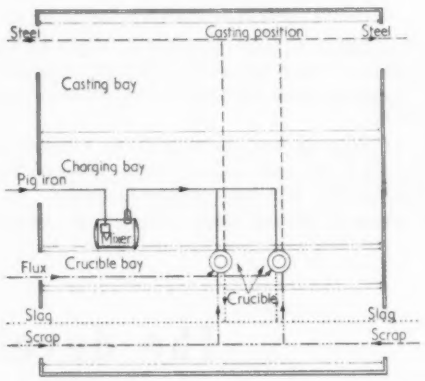

Fig. 2—Linz LD shop

(1 700° C and over). In this connection it is worth mentioning that the life of linings of tar–magnesite, tar–dolomite brick, or ram mixes, was not more than about 150 heats in the early days.

Obviously, lining life not only depends on the quality of the refractory and the method of its application but also on pig-iron analysis, on charging conditions, and on the qualities of steel to be produced. At both Linz and Donawitz these problems were solved early on. At Donawitz, linings made of commercial magnesite brick (burned) yield a life of 500–600 heats (Fig. 3).[3] Linz linings are made of tar–dolomite brick containing a larger percentage of magnesite. The average life of Linz linings is 340 heats. The average consumption of refractory per ton of steel is 4·6 kg at Donawitz and 7·9 kg at Linz.

Here it should be realized that at Donawitz about 20% of the stripped refractory is fit for re-use, while at Linz it is about 50%. With this in mind, the actual refractory consumption at Donawitz is about 3·7 kg/ton and at Linz about 3·9 kg/ton of steel, which is remarkably low. Present information suggests that refractory consumption and, therefore, life of the lining, is quite satisfactory everywhere even though widely different refractories are used. The life of a tar–dolomite brick lining has been reported to be about 300 heats by an LD shop in the Far East, while an American plant with a converter capacity of 80 tons has established a 200-heat figure. Experiments run with synthetic magnesite brick at Donawitz yielded a life expectancy of about 500 heats. Naturally, magnesite refractories will maintain their superiority over other materials. It can be stated, however, that the refractory problem, which seemed most formidable at the beginning, has found a very satisfactory solution, if compared with that of the conventional steelmaking processes.

At Donawitz a symmetrical detachable bottom vessel is used, while Linz uses an unsymmetrical design. Both designs have given good results. Since a bottom charging car is indispensable for a detachable bottom vessel, capital investment will be slightly higher in this case. At Donawitz, vessels are lined so that about 8 h after the last heat the bottom is taken off and stripping of the worn lining starts. From the last heat, relining is begun after about 16 h and takes about 48 h to complete, the new bottom being set in place by the special charging car. After a shut-down of 72 h at the most, burning-in of the new lining begins and takes from 2 to 4 h. After an overall repair time of 74–76 h the crucible is ready for operation. Burning-in of the new lining is by coke and oxygen. While from the operational angle this short time for relining is hardly ever required, it has a significant bearing on theoretical vessel utilization, which, with the conditions prevailing at Donawitz, is over 80%. Between them the two Austrian LD plants have produced some 5·2 million tons of steel for a wide variety of applications, which proves the suitability of the process for the production of quality steels. The

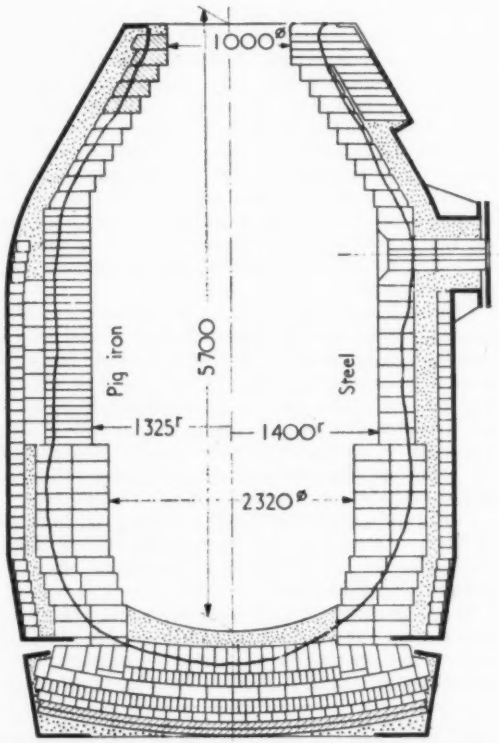

Fig. 3—Vessel used at Donawitz, lined with commercial magnesite brick (burned)

tonnages produced break down into rolling-mill products as follows:

600 000 tons of medium and heavy plates
3 100 000 tons of wide and narrow strip and sheet
100 000 tons of rails and other higher-carbon steels[4]
475 000 tons of wire
50 000 tons of tubes and tube steel
875 000 tons of structural steel, bars and semis.

Added to this are a number of special steels and of low-alloy steels.[5]

Properties of LD steels

On workability and mechanical properties all steels produced by the LD process compare favourably with open-hearth grades, which is in keeping with the good metallurgical conditions obtained by the new process.

The LD process is best suited for the production of very pure steel free from impurities, especially detrimental elements. Since the refining gas is commercially pure oxygen, 99·5%O_2, and the reactions take place in a vessel shaped so as to prevent any admission of atmospheric nitrogen, no nitrogen pickup can occur during the process. Owing to the vigorous development of CO during refining, N contained in the charge is removed to such an extent that the N content of the steel is down to about 0·002%, which can hardly be achieved by the OH process. In the same way, very low contents in hydrogen are obtained. The rapid formation of a highly reactive, high-basicity slag creates favourable conditions for the removal of phosphorus and sulphur. As in the OH process, dephosphorization is completed before the carbon end-point is reached; desulphurization attained is even better than in the open hearth. With P contents up to 0·200% in pig iron, as is the case of the hot metal used at Linz and Donawitz, it is easy to keep the P content in the finished steel to less than 0·20% in one slag operation. The S content of LD steel depends on the amount of S in the pig iron as well as on special measures taken for its removal, such as desulphurization with soda. Soda treatment produces LD steels of 0·020%S max. (if necessary 0·015% max.) when operating on pig irons containing as much as 0·080% S. Owing to the restricted zone of oxygen impingement on the bath surface, the temperatures produced are high enough to reduce the amounts of certain impurities, e.g. As, Pb, Zn, and (partly) S, by evaporation.

The cooling requirements of the LD process can easily be met by using either home scrap or virgin ore exclusively. Cooling scrap additions will vary pig-iron analysis and will change with the composition of the steel made. For Donawitz-type pig iron containing about 0·1%Si the addition is about 10% of the charge weight, and about 30–35% for a pig containing about 1·6%Si.

The use of these pure materials is the reason why LD steels are very low in Cr, Ni, Mo, etc., undesirable elements that are unavoidably introduced where purchased scrap is used, as in the OH process. At Donawitz the total amount of Cr, Ni, Mo, and Cu is less than 0·10%. Taking into account also that LD steels show the same oxygen content as OH steels of the same C and Mn contents, it is quite obvious that LD steel is a material of high chemical purity.

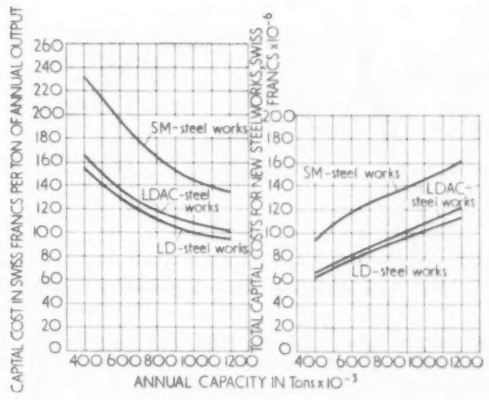
CAPITAL COST IN SWISS FRANCS PER TON OF ANNUAL OUTPUT
TOTAL CAPITAL COSTS FOR NEW STEEL WORKS, SWISS FRANCS x 10⁻⁶
SM-steel works
LDAC-steel works
LD-steel works
SM-steel works
LDAC-steel works
LD-steel works
ANNUAL CAPACITY IN Tons x 10⁻³

Fig. 4—Comparison of outlay calculations for steel shops of different annual capacities

This is fully borne out by the behaviour of LD steels in practical service. The comparatively high degree of freedom from detrimental elements, particularly from P and N, makes LD steel at least equal to OH steel with respect to ageing characteristics, and it is superior in some other respects. Excellent welding characteristics of LD steel and its qualities in the welded condition are also partly due to the low sulphur content that can be achieved. Owing to its low hydrogen content, LD steel shows a pronounced advantage over OH and electric steels in its susceptibility to flaking.

Higher-carbon steels are made by the 'catch-carbon' technique. Once again it should be pointed out that in the production of higher-carbon and rail steels by this technique the reproducibility of results,[5] even with specifications for C as close as 5 points, is as good as that established for the open hearth; at Donawitz the reproducibility is about 94%.

It is true that, owing to the rapidity of the refining reactions in LD steelmaking, a high degree of skill and experience is demanded of the engineers and shop supervisors. Also, it is not always possible to have flash (or rapid) analyses made.

Experience in other plants

The highly satisfactory results obtained by the two Austrian LD shops were attractive enough to induce companies in various other countries to introduce the new process. Generally, the deciding factors were similar to those that in the past had given the impulse for the development and introduction of the LD process in Austria: (*a*) the excellent quality of the steel produced under economically favourable conditions, (*b*) the scarcity of scrap supplies, which frequently forces a steel mill to make-do with home scrap only, and (*c*) the wide range of pig irons that can be worked in the LD converter. In addition, the cost of a new LD shop is only about 70% of that required for an OH shop of the same capacity, which is clearly revealed in Fig. 4 showing a comparison of outlay calculations for steel shops of different annual capacities. At present 14 LD shops totalling 31 converters are in operation; their yearly capacity totals about

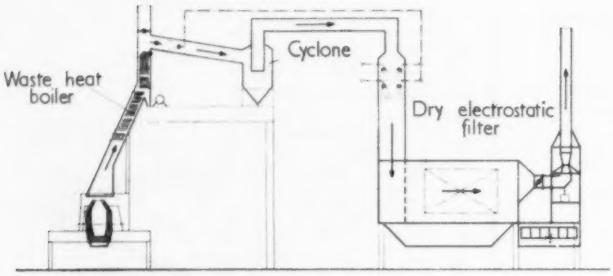

Fig. 5—Lurgi fume-cleaning system at Donawitz

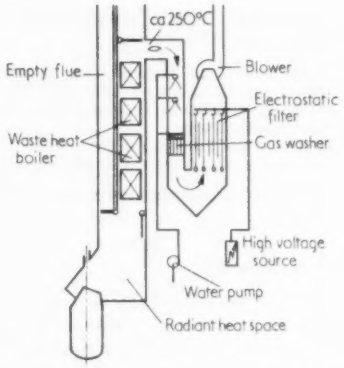

Fig. 6—Fume-cleaning system at Linz

8·4 million tons. Another 13 LD shops with 23 converters are under construction; their capacity will total about 6·5 million tons. The pig irons used by these shops vary in analysis as follows:

	%
C	3·60 – 4·60
Si	0·05 – 2·50
Mn	0·30 – 3·50
P	0·080– 0·40
P	1·70 – 2·00

As has been mentioned, the refractory lining differs from plant to plant and lining life averages 200–350 heats according to present information. There is a still wider difference in vessel sizes. With volumes of from 15 to 60 m³ the charge weights range from 15 to 80 tons.

Some of these plants have satisfactorily proved in running operation that the new process is by no means limited by the size of LD vessels: they produce LD steel in 80-ton converters, whereas operations were started in Austria on 30-ton vessels. This figure of 80 tons does not imply, however, that it is the limit of vessel capacity. To our knowledge, one 80-ton vessel shop has recorded tap-to-tap times of about 60 min, which is 80 tons/h, or 45 s/ton of steel. Compared with this the figure of 40–42 tons per hour, achieved by the largest US OH furnaces of from 500 to 600 tons capacity, is by no means impressive, if it is considered that to some extent these large units work on duplex metal. Considering vessel size from another angle it is interesting to note that at present the smallest vessel hitherto under construction with a volume of 4·5 m³ will operate on a charge weight of 5·5 tons.

Fume

In the past, a formidable problem was presented by the clouds of reddish smoke or fume developed in LD steelmaking by iron evaporation. Consisting of very fine particles, mainly ferric oxide, in sizes down to less than 1 μ, this dust gave rise to iron losses amounting to not less than 0·6% of charge weight. With a production of 50 tons of steel per hour, about 500 kg of red fume were carried away by the outgoing gases. Since then this problem has been overcome by several gas-cleaning systems, e.g. the Waagner-Biro and Pease-Anthony systems (wet cleaning), and the Lurgi system (dry cleaning).[6]

Figure 5 shows the Lurgi system introduced into the Donawitz plant. After passing through a waste-heat boiler installation for superheated steam the outgoing gases are admitted to the Lurgi cleaning plant. The boiler plant was installed by Waagner-Biro. Steam generation is about 0·31 tons steam per ton of steel, at 450° C and at 50 atm. Dust precipitation is by electrostatic precipitation, the collectors being charged with a pulsating d.c. current. The cleaning efficiency of the plant is 99·88%.

Figure 6 shows the gas-cleaning plant installed and perfected at the Linz LD shop. After cooling in a boiler plant the waste gases were subjected to wet mechanical cleaning, followed by electrostatic finish-cleaning; the cleaning efficiency of this plant is 99·7%. While a boiler plant with cleaning system attached certainly constitutes a major capital investment, it also represents a credit item for steam and recovered ferric oxide dust, by which the iron yield of the process can be improved by 0·6%.

Costs and application

For the first time in the history of steelmaking, a surplus of energy has been obtained, which can be calculated as follows: the energy requirements of an LD shop (including oxygen plant, cranes, and other items) totals 150 000 kcal/ton of steel. From the waste heat boiler 230 000 kcal of energy in the form of steam is produced per ton LD steel. Thus there is a surplus of 80 000 kcal/ton of steel, which can be used to generate electricity.

In any branch of technical science, and particularly in steelmaking, there is a long way to go before an idea, however good, can be developed into a practical process. This holds for the LD process also. Extensive laboratory experiments were followed by pilot operations in small but operational production units, before the process could enter its final stage of development on a commercial scale. Even then work was continued to obtain optimum economic results and to prove the capability of the process to produce steels meeting a wide range of specifications. Furthermore there was the problem of raw materials, which vary widely from place to place, and is one of the main factors on which iron and steelmaking everywhere depends. Thus the metallurgist entrusted with development work of this kind in his own plant is faced with a formidable task. Naturally, the development engineers at Linz and Donawitz were obliged to tackle their own problems first and had no small task

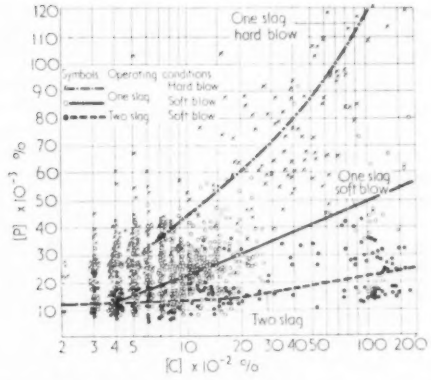

Fig. 7—Relation between C and P under various operating conditions at Yawata steelworks (Japan)

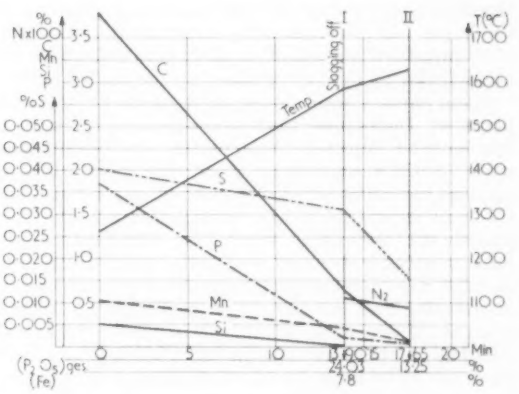

Fig. 8—Curves showing progress of refining with the LDAC process at the ARBED plant at Dudelange

to reassure consumers as to the quality of the new steel. Another difficult consideration was cost, which could not be dealt with off-hand, since the figures had to be compared with those obtained from the OH and electric shops existing at both Donawitz and Linz. Today, however, all these difficulties have been overcome, and the several million tons of LD steel exported to many foreign countries in the past years may be considered complete proof of success in producing a steel of highly satisfactory quality.[7]

It is well understood that the first LD shops to follow the Austrian example in other countries, e.g. at DOFASCO, Canada, and at Jones and Laughlin, USA, were simply adopted for the reason that the available pig irons were similarly low in phosphorus and the production programme was primarily concerned with low-carbon grades of steel.[8] However, development work carried out at Donawitz in producing higher carbon steels by the catch-carbon technique, and making low-alloy steels, succeeded to such an extent that the production of quality steels on a large scale by the LD process was established. Thus the way was prepared for companies specializing on quality steels exclusively, and three LD shops of this type have meanwhile been put into operation in Western Europe.

A different problem was encountered when, as in the case of the steelplants in Japan, it was required to operate the LD converter on a pig iron containing 0·40% P.

Figure 7 shows results obtained from experimental runs made by the Yawata Iron and Steel Co. A suitable technique was found and the satisfactory results obtained showed that, with steel specifications of up to 0·10%C, pig irons of 0·50%P max. can be worked with single-slagging to give a steel of 0·030% P max., while in two-slag operation the P level is further reduced to 0·020%P max.

Yet another approach had to be found when working higher-phosphorus pig irons. It is worth mentioning here that many years ago experiments were made at Donawitz to ascertain whether or not it was possible to produce LD steel from pig irons containing 0·5–1·5%P. First reports on these experiments were made in 1952.[9] More recently, Trenkler[10] has published several detailed reports on the top-blowing of high-phosphorus pig irons (0·5–1·5%P), which were based on experiments run at the Linz LD plant. Here it was established that blowing of these irons under LD conditions yielded good (and economic) results, provided a technique was adopted of double slagging accompanied by the addition of ore fines before the first tilting of the converter for slag run-off, and re-use of the final slag in the following operation. Tap-to-tap time is 45 min for a 30-ton converter, which is considerably higher than basic Bessemer heat times. It should be remembered, however, that, as to results, the LD process should be compared with the OH rather than with the basic Bessemer process, even though the latter is operated with an oxygen-enriched blast. It should also be stressed that by the LD process a steel is produced that is at least equal to OH steel.

Further problems were met when dealing with high-phosphorus pig iron of 1·7–2·0%P, such as are used by basic Bessemer plants in Western Europe. Using a double slagging technique, the Mannesmann and Pompey plants have so far produced several thousand tons of LD steel.[11] This technique provides that the major portion of the phosphorus contained in the bath is made to pass into the first slag, which represents a saleable type of fertilizer containing about 20%P_2O_5 and about 6%FeO. In this first period of the process the P levels of the bath are reduced to 0·5% and 0·2% respectively. In the slag-off, the entire volume of the first slag is removed from the vessel. Final dephosphorization occurs during the second period of the process; the final slag contains less than 6%P_2O_5, while FeO contents range between 15 and 25%, depending on blowing conditions and on carbon end-point. This final slag is retained in the crucible and re-used as first slag in the following operation to avoid iron losses.

Lime-powder injection

After years of experiment, reports have recently been published on a modified LD process featuring

the injection of pulverized lime into the vessel through the lance. At Donawitz also, experiments were made with primitive makeshift tools to find out about the possibilities of lime injection and the use of lime of varying particle size. However, it was in the ARBED plant at Dudelange that a commercial method of lime-powder injection was found. In co-operation with CNRM a remarkable plant was installed in an existing basic Bessemer shop with 26-ton vessels, and the equipment necessary for performing the new process was provided. From long experience in the field of using pulverized materials, particularly lime powder, for metallurgical purposes, the problems of introducing into the oxygen jet perfectly controllable amounts of lime were quickly solved. Some difficulties still had to be overcome in lance design, and new ways had to be found by which ducting of the oxygen–lime mixture to the lance itself was safeguarded.

A lucid report on this process, the LDAC process, has been published by Metz.[12] To date about 20 000 tons of steel have been made in production conditions with good results in quality and operational economy. This shows that the LD process is applicable even to basic Bessemer pig iron.

Lime powder of less than 2-mm particle size is added in controllable quantities via a ' zellenschleuse ' (a revolving set of chambers metering out predetermined quantities of lime powder) to the jet of oxygen directed against the metal bath. The flow of oxygen and lime, also the distance between lance nozzle and bath surface, is adjusted to ensure rapid formation of a foamy slag. Positive control of process reactions is achieved so that spilling of slag and other iron losses are avoided. Thus a high iron yield is obtained, accompanied by a very satisfactory degree of dephosphorization. Figure 8 shows the progress of refining. In a first period of about 14 min blowing time, the C content is reduced to about 0·7% while P is brought down to less than 0·2%. At this point the blow is interrupted and the first slag flushed. This slag contains 20–27%P_2O_5 and 6–9%Fe, is practically free from granulated metal, and shows excellent solubility. Blowing time to the desired end-point and the amounts of cooling scrap added for temperature corrections depend on the C content and the temperature level of the bath after the first blow. The second blow lasts from 3 to 5 min. Despite the shortness of this second blow, a slag of satisfactory fluidity is formed by the lime powder injected with the oxygen jet. With an iron yield of about 90% this process has proved itself in commercial operation.

A pig iron of percentage composition:

C	Si	Mn	P	S
3·35–4·12,	0·10–0·75,	0·31–0·65,	1·60–2·15,	0·032–0·085

is converted into a steel with P content below 0·025%, and carbon levels of less than 0·10% are maintained even below 0·020% P. The content of S, N_2, and O_2 is at the same low level as with normal LD steel. Low consumption of oxygen (55–56 m^3/ton of hot metal) and lime (105·5 kg/ton of hot metal), the fact that fluxes (fluorspar) are not required, high speed of refining, and high yield of crude steel renders this process highly economic. If a tap-hole converter is used, the second slag can be kept in the vessel and re-used in the following operation; this technique results in increased yield and reduced consumption of lime.

CONCLUSIONS

In the foregoing the attempt has been made to outline the present state of the LD and LDAC processes. The capacity of the LD process and of the LDAC process to cope with high-phosphorus pig irons is sufficient to show that the conversion of medium-phosphorus irons is also possible, although at present there are no known steelplants operating on such pig irons. At each of the 27 LD shops in operation or under construction, different conditions were met in raw materials, desired products, price of raw materials, and availability of labour. The problems to be solved therefore differed widely from place to place. The planning of any new LD shop will doubtless have similar problems depending on local conditions. In one vital respect, however, all LD shops have the same advantage, no matter where they are located: their comparative independence of the pig-iron analysis. Steel companies choosing an LD installation will therefore also be free to choose the source of their ore supplies.

The LD process is easily adaptable to specific production requirements. The capacities of plants in operation today vary from 20 000 tons to 1 300 000 tons of steel per year. The economy of the process was clearly revealed during the industrial recession of the past years, when all of the LD shops in Western Europe, North America, and the Far East kept producing at their normal capacities. On the other hand the LD process is readily adaptable so as to suit temporary requirements for crude steel, since continuous operation is as easy as two-shift operation or operation on workdays only.

It is true that the rapidity of the process reactions requires operating personnel of considerable mental and physical skill. Yet it should be remembered that the LD process has been operated even in countries that have no long-standing tradition of steelmaking. With an overall capacity of more than 8 million tons per year the existing LD shops produce both bulk and quality steels, for which the process is excellently suited.

Certainly the development of the LD process cannot be regarded as complete after only 6 years of commercial operation, when not even the open hearth has been fully explored after 100 years. We are, therefore, further concerned with a variety of problems, from the solution of which further improvements and operational refinements can be expected. It is reasonable to assume that by the installation of new shops the LD and LDAC process will run up to a capacity of 20 million tons in the near future.

It is a pleasure as well as an honour to discuss a new and rapidly accepted steelmaking process here in the UK, for we do not forget that 100 years ago two great inventors and engineers, Sir Henry Bessemer and Sidney Gilchrist Thomas, introduced their respective processes and they pointed out the possibility of using oxygen. Up to the present the Thomas process has had no equal for economy in the con-

version of high-phosphorous pig irons. Many ideas of those famous inventors have been adopted fundamentally in the LD process, ideas whose further development has put us in a position to achieve still larger converter capacities and better performance, to become independent of type of pig iron, and to supply steel of a quality hitherto considered the domain of the OH or the electric furnace.

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Fundamental aspects of scale on mild-steel strip

By S. Garber, B.Eng.(Met.), Ph.D.

SYNOPSIS

During the production of mild-steel strip, the loss of metal as oxide ranges from 5·9% to 8·4%. The thick scale formed on the ingot and slabs is removed during mechanical working operations. The thin scale formed on the hot strip requires a separate treatment for its removal which is normally a continuous pickling.

Fundamental knowledge of the nucleation and growth of the scale layer is reviewed and the unstable nature of wüstite below 570° C is considered.

Types of scale found in practice are described for the ingot and billet (and slab), and the author's observations on the structures of hot-rolled-strip scale are presented. Two principal types of structure were found on the strip and their deviation from the normal type of scale structure is believed to be associated with the temperature history of the strip.

In continuous pickling the role of the mechanical scale-breaker is to give the acid quicker access into the scale and the metal. The fundamentals of pickling are considered and it is concluded that, contrary to the classical theory, the ideal scale structure for optimum pickling speeds is one in which a continuous layer of wüstite is in contact with the parent metal.

Finally, the possible directions of future lines of work are discussed, including the possibility of reducing scale losses and improving the pickling operation by increasing the efficacy of the scale-breaking operation, and conditioning the scale structure. 1681

Loss of metal to oxide

IN THE PRODUCTION of mild-steel sheet and strip, layers of scale form on the metal on five different occasions during the processing from the molten metal to the hot-rolled band stage. The first is found on the as-cast ingot; subsequent layers are produced in the soaking pits, slabbing operation and storage, slab re-heating, and finally during rolling, coiling, and storage of the hot strip.

Factors such as surface finish, mechanical properties, and coating behaviour, as well as production costs and yields, are affected to some degree by this oxidation. The approximate figures in Table I briefly sum up the loss of metal at the various stages. They have been collected from the literature,[1–4] private communications, and the actual observations of scale thicknesses.

Excluding scale found on the as-cast ingot, the total figures for metal loss from the ingot (soaking pit) stage to the hot-rolled strip (coiled) range from 5·9% to 8·4%. Even solely in terms of increasing the yield of finished product, it seems economically worthwhile to consider where and how it might be possible to reduce these losses.

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Many practical operators feel that an extensive oxidation of the surface is essential to remove surface defects that have developed during the casting and freezing of the ingot, so that the oxidation losses in the ingot and slab stage are considered as part of the cost of producing a defect-free surface on the strip. Assuming that a heavy scale is essential in the ingot re-heating stage and that the 1·5 to 2% loss is warranted, there is still a strong argument for reducing the

TABLE I

Loss of metal at various stages, ingot as-cast, scale 0·080 in. thick

Ingot	Soaking pits	1·5–2·0%	5·9–8·4% Metal loss by weight as scale
Billets and slabs	Shaping and storing	2%	
Billets and slabs	Re-heating	2% (2·5–3%)	
Strip	After coiling	0·4–2·6%	

remaining 4·4 to 6·4% metal losses. As the stored slabs are usually inspected and if necessary scarfed before re-heating, the loss of metal in the slab re-heating furnace is unwarranted. With the availability of cheap nitrogen, the possibility of doing (*a*) the cooling after slabbing, (*b*) the re-heating of the slab and, (*c*) the hot rolling (or part of it) in a neutral atmosphere, might be considered.

It may seem impractical to prevent oxidation completely from the slab to the hot coiled strip, but to reduce the amount of scale produced on the slab, both when cooling and in the re-heating furnace, and also on the coiled strip, seems both practical and practicable. For example, this could be achieved by (*a*) cooling the slab with water sprays as it leaves the slabbing mill for transfer to the slab yard, (*b*) cutting down the slab reheating time through more rapid heating and less soaking, and (*c*) improved cooling of the strip on the run-out table or in the coil.

Removal of scale

Removal of the relatively thick scale on reheated ingots and slabs does not present any particular problem. Scale formed on the ingot is normally removed by primary working in the cogging mill; however, reheating scale has to be removed from the slabs otherwise parts of scale are embedded in the surface of the metal and they persist in the hot-rolled strip. Thick scale is removed by some form of slight plastic deformation of the slab, assisted by high-pressure water jets.[5, 6] Air jets blow the loosened scale off the metal before its entry into the working stands.

Removal of scale on strip is dictated by the fact that the scale may be heterogeneous and that its satisfactory removal is dependent on removing all of it, including the most difficult parts. Bullough[7] has described the many electrical, mechanical, and chemical methods of removing scale that have been developed. Continuous acid pickling is used predominantly in the large-scale production of mild-steel strip, and none of the other methods has been able to supplant it.

Continuous pickling lines in current use have been developed over many years, and with local variations they are normally built on the same basic pattern.

SCALE FORMATION AND STRUCTURE

The surface oxidation of metals at high temperatures has received a great deal of attention since Tammann first considered the laws governing this process. In a critical survey that goes up to 1952, Kubaschewski and Hopkins[8] have ably summarized the research dealing with this problem.

Scale thickness

Pfeil,[9, 10] found that on ordinary carbon steels oxidized at high temperatures for an appreciable time, the scale consists of three layers of oxide. The innermost layer is wüstite (ferrous oxide); the middle layer is magnetite (ferroso-ferric oxide), and the thin outermost layer is hematite (ferric oxide). They have the following formulae: the outer layer (hematite) is Fe_2O_3, the middle one (magnetite) is Fe_3O_4, but the innermost layer (wüstite) which is normally described as the stoichiometric compound FeO is more accurately represented by $Fe_{1-y}O$, where y is a measure of the concentration of the vacancies.[11]

The thickness of the scale depends on both temperature and time of oxidation and proceeds approximately according to a parabolic law, $x^2 = kt$, where x is the increase in weight, k is a temperature-dependent constant, and t is the time. The relative thicknesses of the various oxides generally depend on the temperature of formation.[12]

Paidassi[13] studied the kinetics of oxidation of pure irons in air between 700° and 1 250° C. He found that with isothermal oxidation conditions, and after the unstable initial growth, the adherent scale is always composed of three continuous and compact layers of hematite, magnetite, and wüstite. Their relative thicknesses remain constant at 1%, 4%, and 95% of the total scale thickness. On a scale thickness of 0·0005 in. there should be a layer of Fe_2O_3, 0·000005 in. thick. This, of course, cannot be resolved on optical microscopes and it may explain the apparent absence of Fe_2O_3 from many of the structures observed by the author. On the other hand, up to 900° C oxidizing temperature the observance of Fe_2O_3 is not reported for times less than 15 min.

Nucleation and growth

Edwards and Pickering,[14] using electron microscopy were able to observe the initial nucleation and growth of the oxidation of mild steel up to 500° C. The oxide was initiated by whiskers which developed into platelets after an immediate kinking. If this whisker growth is analagous to that observed on metals, then the oxide nucleation and initial growth must develop with the spiral growth of a screw dislocation from the surface of the metal.

At IRSID and other laboratories near Paris, results to date show that early oxide growth is definitely epitaxial and occurs at the surface of the metal along crystallographic planes which have a definite relationship to the orientation of the individual metal grains at the surface.

Engell[11] has pointed out that the diffusion of the iron outwards through the wüstite layer occurs by a vacancy mechanism so that the oxygen does not diffuse inwards through it.

Tracer techniques used by Himmel, Mehl, and Birchenall,[15] have shown that wüstite grows largely by diffusion of cations, hematite by diffusion of anions, and magnetite largely by anion diffusion with an appreciable contribution from cation diffusion above 620° C. According to Birchenall the overall growth is governed by the growth rate of the wüstite. However, Kubaschewski and Hopkins[8] suggest that

the mechanism is not that simple and because of apparent non-uniform experimental conditions, the elaboration of a simple mechanism based on equilibrium involving certain types of lattice defects cannot easily be worked out.

Breakdown of wüstite

The two higher outer oxides are stable at room temperature, but the wüstite is unstable below 570° C.[10, 16] Pfeil[10] considered that the decomposition takes place as $4\ FeO \rightarrow Fe_3O_4 + Fe$. Collongues, Sifferlen, and Chaudron[17] showed that the wüstite transformation is relatively slow and highly temperature-dependent. The isothermal transformation curves of wüstite are similar to the S-curves of steel. The nose of the S-curve giving the fastest rate of breakdown occurs at 480° C and the oxygen content of the wüstite determines the position of the curve on the time scale. Increased oxygen contents move the curve to the left. At 480° C the breakdown of the wüstite begins at 90 s and 100% transformation is completed after 40–50 min. Moreau and Cagnet[18] also found that the decomposition of wüstite is easily retarded so as to produce a completely non-magnetic product at room temperature.

Fischer, Hoffmann, and Shimada,[19] and Fischer and Hoffmann[20] also showed the importance of the rate of cooling on the breakdown of wüstite in bulk. The progress of the breakdown was followed by both X-rays and careful microscopic observations. The transformation of the wüstite is not a simple decomposition to magnetite and iron. Depending on the oxygen content and the rate of cooling, the breakdown products can be wüstite of a lower oxygen content and increased lattice parameter, magnetite, and iron. It can be concluded that under slow cooling conditions, the inner wüstite layer of the scale might be more complex than a single homogeneous layer.

Identification of oxides

Considering the complex scale structures that can occur, care must be taken in the identification of the various oxides. The X-ray diffraction technique is the most useful for obtaining the overall composition of the scale. The structures and lattice spacings of the various oxides are well known and are to be found in the ASTM reference cards. However, the most convenient means of examining the distribution and position of the various oxides is by optical microscopy. On an etched scale specimen, the wüstite appears dark relative to the magnetite, and hematite is the lightest. If the particles are large enough to resolve, the harder phases should stand in relief to the softer ones.

In studies of the scales on wire rod, it was found that microhardness tests could be used to identify the various oxides seen under the microscope.[21] Hematite is over 1 000 DPH, magnetite is of the order of 420–500 DPH, and the wüstite layers are the softest at 270–350 DPH.

Structure of scale in practice

Scale on ingots and billets

Moreau[1] found that there was an appreciable amount of scale on the as-cast ingot. The minimum thickness observed was 0·080 in. The major constituent was wüstite, and it varied a great deal in composition. The steels examined were nominally silicon-free, but this element was present in the scale as fayalite (Fe_2SiO_4); alumina and manganese oxide were also found.

The ingot scale produced after heating in the soaking pits at between 1 050° and 1 250° C showed a macroscopic two-layered structure. The outer one had a compact crystalline appearance and it was composed of hematite, magnetite, and wüstite. The innermost layer in contact with the metal was porous and consisted of wüstite with intergranular fayalite. The proportion of fayalite increased towards the oxide–ingot interface. The loss of metal as oxide varied, but the average figure was 1·5 wt-% on 4·5-ton ingots.

There has been no specific study of scale on slabs. Nevertheless, because of the similarities in the production and re-heating of both slabs and billets, the results obtained in a study of the latter are probably applicable to the former.

Scale produced by the re-heating of billets has been examined by Moreau and Cagnet.[2] The thickness varied from 0·005 to 0·012 in. Scale structures were similar to those found on the re-heated ingot. Beneath the layered structure of scale, which was easily detached, there was a complex zone of oxidation (sub-scale) consisting of a mixture of metal high in nickel, copper, ferrous oxide, fayalite, ferrous sulphide, and pores. When fuel oil was used to heat the billet furnace the proportion of sulphide in the sub-scale increased. The continued presence of silicate indicated that the inner portion of the ingot scale had not been fully removed during the primary working.

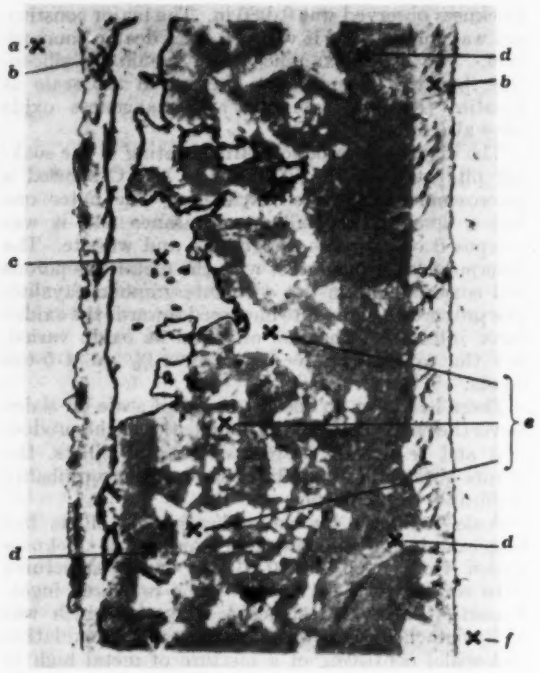
The loss of metal by oxidation during and after the primary rolling was about 2 wt-%. Loss due to the re-heating of the billets was also quoted as being about 2 wt-%.

Scale on hot-rolled strip

In the absence of information on the structure of scale found on the hot-rolled strip, samples of narrow strip (8–8½ in.) from an old and new mill in the same works have been metallographically examined. Specimens were taken from four coils, one from the old mill and the remainder from the new one. Where possible, samples were taken from three coil positions; the leading, middle, and trailing portions, and across the width of the strip.

Four distinct metallographic structures were observed. They are labelled structures *A*, *B*, *C*, and *D* for purposes of identification, and they are illustrated in that order in Figs. 1–4. The etchant was a solution of citric acid, (10 g of citric acid in 100 cm³ of 2% Nital). With this mixture, very little attack on the parent metal occurs.

Structure *A*, Fig. 1, is associated with the thicker portions of the scale. The thin outer layer is apparently magnetite; the thicker inner layer appears to be a matrix of darkly etched wüstite containing a lighter, coarse precipitate of pro-eutectoid magnetite and large islands of a third phase. This latter phase is marked by its sharp boundaries whereas the boundaries between the other phases are more diffuse.



(*a*) Fe (*b*) Fe_3O_4 (*c*) FeO (*d*) Transformed FeO (*e*) Fe_3O_4 precipitate (*f*) Mounting

Fig. 1—Scale microstructure *A* × 100

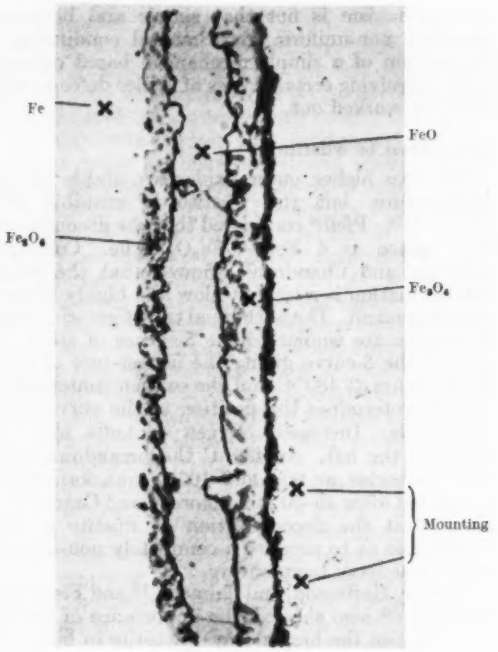


Fig. 2—Scale microstructure *B* × 1 000

In places there also appeared to be a thin layer of primary magnetite in contact with the parent metal. However, it was not a continuous layer and it was not always sharply defined.

Figure 5 illustrates the microhardness results on the same field as in Fig. 1. In fact the matrix of the thicker inner layer had a microhardness similar to the other primary magnetite layer and the coarse cuboid precipitate of the pro-eutectoid magnetite. Only the light, sharply defined islands are as soft as wüstite. This dark matrix is considered to be a transformed wüstite.

Structure *B*, Fig. 2, consists of three layers. The microhardness tests establish the outer one as magnetite, the middle one as wüstite, and the inner layer next to the parent metal is also magnetite. This type of structure had been previously seen[21] in a wire-rod scale but it was considered rather unusual. However, it was fairly common in the hot-rolled strip examined.

Glancing-angle X-ray tests confirm that magnetite is the major phase in structure *A* and that structure *B* has considerably more wüstite. On the strength of the theory of breakdown outlined earlier, this tends to confirm that the transformed wüstite in structure *A* is predominantly magnetite.

Structure *C*, Fig. 3, appears to be a development from structure *B*. Instead of the wüstite occurring as a more or less continuous layer, it occurs as stringers of islands in a matrix of magnetite.

Structure *D*, Fig. 4, appears to consist of an outer magnetite layer and an inner layer of transformed

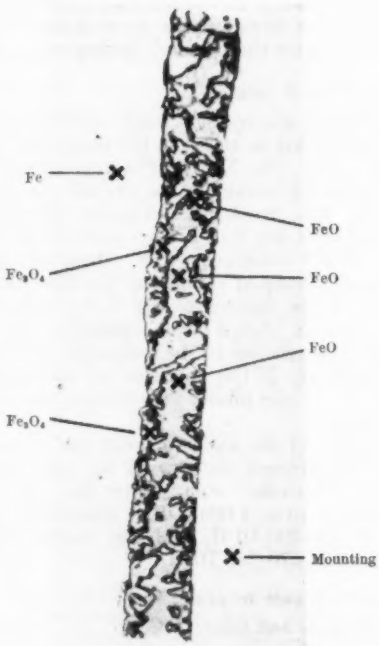


Fig. 3—Scale microstructure *C* × 1 000

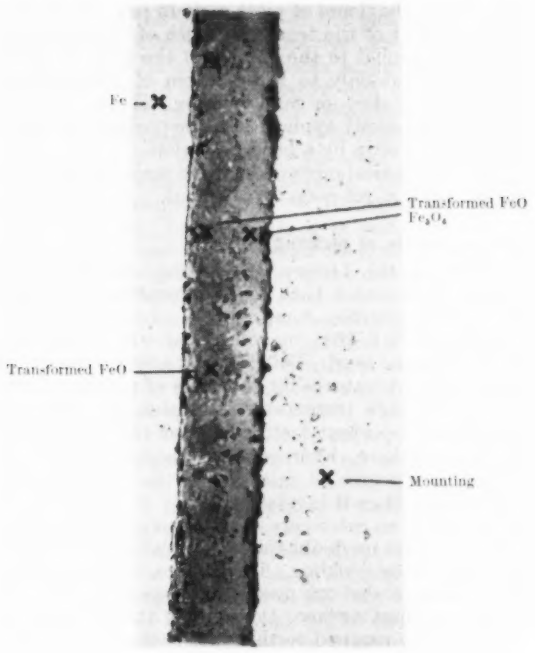


Fig. 4—Scale microstructure *D* × 1 000

Fig. 5—Relative microhardnesses of phases in structure *A*, same field as Fig. 3 × 1 000

wüstite. The boundary between the two layers is diffuse like that in structure *A* and there is the occasional small island of sharply defined wüstite. This structure is associated with thinner parts of the scale. Although large islands of wüstite and the cuboid magnetite precipitate are absent, structure *D* resembles a thinly developed structure *A*. On coils finished at higher temperatures, these structures were observed with a thin outer layer of hematite.

The scale structure on each coil varied across the width of the strip and from the leading to the trailing section. On the samples of the coil from the old mill, scale on one side was much thicker than on the other side, and this may be attributed to the method of run-out before coiling. The strip in this case was looped on the edge of the run-out table, and the temperature of the strip side facing inwards in a loop presumably decreased at a slower rate than the outward facing side.

On the strip from the new mill, leading sections of the coils have a thicker scale than the middle and trailing parts. This is probably produced by the practice of not turning on the high-pressure water descaler until the work rolls grip the leading edge of the strip. Temperature gradients in the strip as well as the rate of cooling must obviously play an important role in determining the local thickness and structure of the scale. The scale has not been weighed, but an estimate based on the range of measured scale thickness (0·00025–0·0025 in.) gives a loss of metal to oxidation of about 1–2 wt-% of the hot-rolled strip.

Summary of the distinctive features of practical scale structure

The heavy scale found on the ingots and billets is, as expected, composed predominantly of the three conventional layers of iron oxides. Notable features are the presence of fayalite towards the parent metal on both the ingot and billet scale, and, in the case of the billet, heterogeneous sub-scale consisting of a mixture of fayalite, ferrous oxide, ferrous sulphide, metal enriched in nickel and copper, and pores.

The relatively thin scale observed on hot-rolled strip shows in the case of structures *A* and *D* (Figs. 1 and 2) an inner layer of a complex structure of transformed wüstite of the kind associated with slow cooling. In the case of structures *B* and *C* (Figs. 2 and 3) the existence of an innermost layer of the higher-oxide magnetite was an unexpected feature.

The presence of the inner layer of a higher oxide is explained if the scale becomes detached at high temperatures or blisters develop near the oxide–metal interface.[21,22] However, where a continuous scale exists in contact with the metal, as in Fig. 2, structure *B*, the origin of the inner magnetite layer is more difficult to visualize. In normal fast-cooled scale, the wüstite shows a gradient in composition: the oxygen content is lowest at the oxide–metal interface. Hence the zone of wüstite in contact with the iron is normally the most unlikely part to convert to magnetite. A tentative explanation is that the oxide in structure *B* is wüstite at the higher temperatures. At some stage in the cooling, conditions are favourable for the diffusion of iron ions from the oxide inwards, to

where they deposit on the existing metal. The zone of the wüstite that has been depleted of iron then has an excess of oxygen and it then transforms to primary magnetite.

This type of mechanism depends on the relative diffusion coefficients and bond energies, so that it is highly temperature-dependent. The cooling history of the scale from the high oxidizing temperatures is definitely an important factor. An alternative explanation is that some form of internal oxidation occurs at low temperatures (below 570° C) which produces the inner layer of the higher oxide.

REMOVAL OF SCALE

The most prevalent method of removing scale from strip is by way of a continuous process of mechanical break-up followed by pickling in acid. The aim is to remove all scale as quickly as practicable so as to keep in step with the general rate of flow of material through the chain of manufacturing processes.

Fundamentals of mechanical scale-breaking

The function of mechanical scale-breaking is to crack the outer higher oxides which are less soluble and to give the acid access to the inner scale and the metal. Martin[23] and Greenberger[24] have indicated how the introduction of an improved scale-breaker effectively increased the pickling action of acid so that pickling speeds could be increased three to four times.

The scale-breaking action is dependent on the mode of plastic deformation of the strip. One of the current methods is to subject the strip to a reverse bending action around small-diameter rolls before passing it through a roller leveller. Other methods consist of (*a*) passing the strip directly through some sort of processor leveller, and (*b*) giving the strip a small rolling reduction.

The diameter and arrangement of the rolls in a conventional leveller type of scale-breaker should be designed to give the most rigorous surface deformation. Because of the cold work and ageing effects, the severity of the scale-breaking is limited by the maximum hardness of strip that would be accepted by the cold-reduction mill. Yet it is interesting to note that one large steelworks has installed a second scale-breaker on the entry side of the pickling line to speed up the pickling rate. This suggests that the savings achieved by increasing the speed of the pickling line may outweigh the disadvantages of rolling what is a harder strip. Instead of using a bending action, it has been suggested that a twisting action on the strip might be more effective for scale-breaking.[25] However, the results of this method are not available.

The pattern and number of cracks are not only dependent on a particular scale-breaking operation but also on the mechanical properties of the scale. The latter will vary with the thickness and porosity of the scale, and with the proportion and distribution of the oxide phases and their relative strengths.

Engell and Peters[26] and Peters[27] have investigated the tenacity and structure of scale on thick plate. The effects of trace elements and finishing rolling temperature play an important role in determining the properties of plate scale. The laboratory results generally appeared to correlate with the actua descaling behaviours of plate scale in practice.[28] The measurement of the tensile strength of the scale in a direction normal to the surface of the plate is, however, relevant only to the problem of mechanically descaling by shot- or sand-blasting. The conclusions are not necessarily applicable to the problem of breaking scale on strip by a bending action.

The mechanical properties of thin scale on hot-rolled strip have not yet been investigated.

Fundamentals of pickling

Early in the history of pickling, the beneficial effects of increased bath temperatures were noted.[23] In current practice temperatures of 88–99° C with acid baths of 6–26% by volume of 100% sulphuric acid are being used. This is the maximum practical range of temperatures for this type of pickling. Providing the high temperature is maintained and the other less important factors such as the build-up of ferrous sulphate, hydrogen ion concentration, viscosity, and degree of agitation of the bath are also controlled,[7] then it is relatively easy to maintain the acid bath at an extremely high activity. On the other hand, there is no doubt that scales differ in their ease of removal by pickling. In practice, different parts of the same scaled coil need varying pickling times to achieve a clean surface. Considering that all parts of the strip are exposed to the same scale-breaking and pickling treatment in the continuous process, it suggests that the differences in pickling are due to the differences in scale structure.

Winterbottom and Read[29] showed in a remarkable series of photomicrographs how acids preferentially dissolved the thicker inner layer of wüstite but left the two outer layers relatively untouched. It was also found that the scales produced at 900° C pickled faster than those produced between 520° and 900° C. This difference is attributed to the increased concentration of wüstite present in high-temperature scale.

Pfeil, in the discussion of this paper,[29] pointed out that the wüstite after 'slow cooling' transformed as a eutectoid into magnetite and iron ($4\ FeO \rightarrow Fe_3O_4 + Fe$). As the rate of cooling alters the degree of transformation of this inner layer, it also has some effect on the rate of pickling.

Hoar[30] suggested an electrochemical mechanism to explain the rapid solution of the inner oxide layer despite its eutectoid decomposition to magnetite and iron. Hoar assumed that the inner layer is composed of unchanged wüstite, eutectoid magnetite, and iron. The actual proportions of these phases are dependent on the rate of cooling. When the acid comes into contact with the inner layer of the scale, the wüstite matrix (ferrous oxide) readily dissolves and small local electrolytic cells are set up with the eutectoid iron particles acting as the anodes and the eutectoid magnetite (ferroso-ferric oxide) particles as the cathodes. The iron dissolves as the ferrous ion whilst hydrogen deposits at the magnetite cathode which is then reduced to ferrous oxide. In these small cells the relatively insoluble ferroso-ferric oxide is thus converted to the more soluble ferrous type of oxide. The larger massive layer of magnetite is relatively insoluble and as the inner layer of the scale dissolves, the insoluble remainder flakes off.

To explain the variability in the pickling of scale formed at different temperatures and cooled at different rates, it has been further suggested that the cooling history of the scale below 570° C determines the particle size of the wüstite breakdown products, i.e. of the magnetite and iron. For Hoar's suggested electrochemical cell reaction to work rapidly, an optimum sub-microscopic particle size of these products is essential.[7, 23, 31, 32] However, no direct microscopic or X-ray evidence is put forward to confirm this, and there is also disagreement as to what the actual effects are with the different cooling rates.[7, 23, 24, 29, 30, 31]

There have been attempts to 'condition' the scale so that the inner wüstite layer is in the most favourable state for pickling.[23, 31] The treatment consists of an immersion of the hot coils into a tank of water until the coil temperature is below 370° C. This is supposed to (*a*) provide a fine dispersion of eutectoid magnetite crystals of optimum size for pickling, (*b*) disrupt the outer scale, and (*c*) prevent sub-critical oxidation. Some improved rates of pickling were obtained but the overall results were erratic.

The most recent work on scale structures and pickling indicates that theories based on Hoar's suggested Fe_3O_4/acid/Fe electrochemical cell are incorrect. It is quite valid to consider that the cooling rate below 570° C can affect the pickling behaviour insofar as it determines the breakdown of the wüstite. However, it must be emphasized that with a sufficiently rapid cooling rate, the wüstite can easily be retained in the metastable condition, which is distinguished readily from the breakdown structures of wüstite by means of microscopic and microhardness observations. Another determining factor that was not previously considered is that the oxygen content of the wüstite before it is cooled also affects the decomposition rates and products.[17–20] Hence two scales similar except for different oxygen contents in the wüstite do not necessarily give the same inner layer structure even when cooled at the same rates.

Moreover, Wever and Engell[33] have confirmed that the rapid solution in acid of an inner wüstite layer is an electrochemical process. Once the wüstite loses contact with the parent metal, it only dissolves chemically at a relatively slow rate. Engell[34] found that magnetite when in contact with the iron dissolves at about the same rate as when by itself in the acid.

In the absence of a wüstite layer in contact with the parent metal, the pickling action is dependent on the relatively slow chemical solution of the scale and the metal. The evolution of hydrogen at the metal–scale interface tends to blow off the scale.

Where the inner layer of the scale is partially transformed the speed of pickling probably depends on the proportion of wüstite still present and in contact with the metal.

Insofar as batch pickling is concerned, some recent work of the Max Planck Institut is an important contribution to the understanding of its rate-determining mechanism.[33, 35, 36, 37] Their general conclusion is that the batch pickling rate is determined by the thickness of the higher oxides and the density and distribution of the fissures and pores. The higher oxides act as a barrier to the acid and once they are broken down by chemical solution the pickling rate is dependent on the density of the number of passages which allow the acid to penetrate to the wüstite and the parent metal completing the electrochemical cells. The structure of scale is primarily considered from the viewpoint of the density and distribution of the cavities and the protective role of the higher oxides.

DISCUSSION

Considering the electrochemical process which is responsible for the fast solution of wüstite in acids, the ideal scale structure for pickling is one in which there is a continuous inner layer of wüstite in intimate contact with the metal and there is an infinite number of channels for the acid to penetrate through the outer relatively insoluble higher oxide layer(s) to complete the maximum possible number of electrochemical cells (Fe/Acid/FeO). However, if the scale on a strip is non-uniform, it is important to note that the rate of continuous pickling is determined by that part of the scale which is the most difficult to pickle.

Using the ideal scale as a yardstick, one can predict that the structures *B* and *C* (Figs. 2 and 3) are rather difficult to pickle because of the continuous inner layer of magnetite separating the wüstite from the metal. Removal of these scale layers depends on the slower rate of a chemical reaction.

The exact effects of transformed wüstite on the rate of the electrochemical process are unknown but it can be assumed that the rate will be a function of the amount of wüstite in the inner scale layer in contact with the metal. The hardness of the transformed wüstite in structures *A* and *D* (Figs. 1 and 4) is similar to that of primary and pro-eutectoid magnetite except for occasional islands of untransformed wüstite. There is very little of this ferrous phase in contact with the parent metal. The rate of the electrochemical reaction would probably be highly attenuated with these structures.

It is to be expected that, starting with the removal of the slab from the reheating furnace, the corners and edges of the hot metal cool faster than the centre and middle. These thermal gradients more or less follow through into the hot-strip stage. They are generally responsible for the difference in scale thicknesses and structures. This non-uniformity of temperature is illustrated by the variations in metal structure on the transverse cross-section of hot-rolled strip.[34]

Examination of scale on the narrow strip indicates that the pattern of the scale structures roughly follows what might have been the pattern of thermal gradients. However, the pattern is modified by the practice of starting the high-pressure water descalers only after the strip is in the roll gap, (*a*) by the method of run-out, and (*b*) in some cases by the build-up of scale at the exposed edges of the coiled strip.

The mechanical properties of scale under a bending strain are important in the scale-breaking process. It is obvious from the various structures observed in the scale on narrow strip that the absence or presence of wüstite or decomposed wüstite and the mode of distribution of the various phases will determine the cleavage planes in the scale. The bonding or locking between the inner oxide layer and the parent metal would also be a factor.

It is more difficult to predict how scale of the structures *A* and *D* would cleave. The bonding between metal and oxide might be the most significant factor in these cases.

In the light of these arguments, the surface roughness of the metal must be considered as an important parameter when studying the mechanical behaviour of scale under the types of deformation encountered in scale-breakers.

CONCLUSIONS

From the ingot to the hot-rolled strip, the loss of metal to oxide varies from 5·9% to 8·4%. Consideration should be given to the possibilities of minimizing the metal losses. For future development it should be ascertained whether it is worthwhile to decrease scaling by the more rapid cooling of the metal at strategic places along the line, e.g. after the slabbing mill, on the run-out table, and at the coiler, or by the use of a neutral atmosphere wherever possible, or by the more rapid or novel methods of reheating the slab. In the case of billets, induction and resistance heating have been successfully employed. The application of this form of heating to slabs has not yet been introduced.

Scale thickness depends mainly on the time and temperature of formation. Most of the classical work has been done on studies of relatively thick scale equivalent to the heat treatment of, say, ingots or billets. That on hot-rolled strip is relatively very thin and is the product of an early stage of oxidation.

Once the acid has access to the metal and inner parts of the scale, the removal of a layered oxide scale by pickling is fastest when the innermost layer in contact with the metal is wüstite. When the acid comes into contact with the two adjacent phases, an electrochemical cell is created which rapidly dissolves the wüstite. If this ferrous layer loses contact with the iron, the slower chemical solution of the oxide occurs. Magnetite does not form a satisfactory electrochemical cell with iron. However, wüstite can transform below 570° C if cooled slowly and the products as well as the rates of decomposition depend on its original oxygen content and the rates of cooling. The fastest transformation occurs at about 480° C. Hence the problems of the continuous scale removal from strip are associated with the degree of breakdown of the inner wüstite layer. Therefore the coiling temperature of the strip is very important because of the inherent slow rate of cooling in the coil.

Some of the scale structures observed on the narrow strip have an innermost layer of transformed or partially transformed wüstite. Others show a non-classical sandwich type of structure with the inner and outer layers consisting of magnetite and a middle layer of wüstite. Very little is known about the formation of this latter structure, which is certainly not ideal for optimum pickling speeds.

Existing knowledge indicates that if wüstite is cooled fast enough to miss the nose of its S-curve at 480° C, then the decomposition of the wüstite can be more easily avoided. Thus by controlling the structure of the scale to give a continuous inner layer of wüstite, the rapid electrochemical solution of the inner layer can be used to obtain more rapid pickling rates. However, the discovery of a sandwich scale structure indicates that further fundamental background work is necessary to relate the scale structures to their particular thermal history before a more detailed proposal of scale treatment or conditioning can be suggested.

An even more rigorous scale-breaking treatment is plausible. It has already been utilized in practice by the installation of a second scale-breaker without any detrimental effects to the cold-reduction process.

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POWDER METALLURGY JOINT GROUP

Meetings and publications

Theoretical aspects of sintering

THE FOURTH MEETING of the Powder Metallurgy Joint Group was held in London on 29th April 1959, when an informal discussion took place on 'Theoretical aspects of sintering.' The discussion was based on five specially invited review papers, which were published beforehand in *Powder Metallurgy*, the official organ of the Joint Group. The papers were: 'Processes involved in sintering,' by R. G. Bernard (Université de Lyon); 'Recent British developments in the theory of sintering', by G. A. Geach (A.E.I. Research Laboratory); 'Current progress in theories of sintering in the USA', by J. T. Norton (Massachusetts Institute of Technology); 'Recent work on the theory of sintering in the German Democratic Republic', by F. Thümmler (Dresden); and 'The mechanism of sintering in single-component systems', by I. M. Fedorchenko and R. A. Andrievsky (Kiev).

Powder Metallurgy no. 3

The latest issue of *Powder Metallurgy* contains, in addition to the above five papers on sintering, a number of original research papers, synopses of which are given here. *Powder Metallurgy* is published twice a year and is obtainable by annual subscription of 25*s* (post free). Members of The Iron and Steel Institute and The Institute of Metals have a privileged yearly rate of subscription of 10*s* (post free).

The compaction of metal powders by rolling. I—The properties of strip rolled from copper powders, by P. E. Evans and G. C. Smith (Department of Metallurgy, University of Cambridge)

The investigation described is an extension of earlier work ('Symposium on Powder Metallurgy 1954', p. 131: 1956, London, The Iron and Steel Institute, and *Sheet Metal Ind.*, 1955, vol. 32, p. 589), which described the effect of rolling pressure and sintering conditions on the mechanical properties of strip rolled from copper powders. The directional variation of UTS and of elongation of sintered strip are shown to be the same as those of solid copper with a similar microstructure, at least for material with up to 16% porosity. The shape of powder particles and the particle-size distribution have a marked effect on the strength of sintered strip by virtue of their effect on the shape and size of the pores in the sintered material. Measurements of electrical resistance reveal a linear relationship between conductivity and porosity over wide ranges of porosity in both 'green' and sintered strip. The conductivity increases rapidly during the first few minutes of sintering at 1 000° C. Measurements of the resistance in the rolling direction and in the transverse direction, which are independent of local variations in density, have been made on green sheet; the resistance in the rolling direction is higher. A correlation between this result and the mode of particle deformation is proposed, and is elaborated in Part II of this paper.

The compaction of metal powders by rolling. II—An examination of the compaction process

The compaction process is examined in detail. It is shown that, where particle deformation is concerned, compaction by rolling is similar to compaction by static pressing, with the addition of elongation of the particles in the rolling direction when the rolling pressure is sufficiently high. A method for determining the average roll pressure is described. A comparison of the rolling of a metal powder with the rolling of a solid bar, and the determination of the effect of particle shape and mean size, indicates that not only roll/powder friction but also the slip between particles play an important role in the compaction process. This leads to an examination of the flow properties of powders, which are measured in terms of a 'powder-viscosity factor' that indicates whether and at what order of rolling speed a powder can be coherently compacted. Finally, a mechanism of compaction is proposed on the basis of the present findings and on the authors' earlier work.

Production of pure nickel strip by the direct-rolling process, by D. K. Worn and R. P. Perks (The Mond Nickel Co. Ltd, Development and Research Department, Birmingham)

Results are presented of an investigation into the production of pure nickel strip, 6 in. wide × 0·030 in. thick, from carbonyl nickel powder, using compacting rolls $7\frac{5}{8}$ in. dia., arranged in a horizontal plane. Special reference is made to the factors affecting the quality and output of green strip: roll-gap dimensions, the head of powder above the roll gap, rolling speed, and raw-material properties. It is shown that for a given compacting mill, the thickness of green strip that can be produced is strictly limited and that it becomes progressively more difficult to achieve the limiting thickness with increase in rolling speed. A method of reducing the detrimental effect of high rolling speeds is described.

The continuous sintering and subsequent processing of directly rolled strip, using conventional cold-rolling and annealing plant, are then considered, and the properties of fully processed material are compared with those of strip produced from melted and cast carbonyl nickel pellet. It is concluded that the direct-rolling process is capable of producing on a commercial basis nickel strip having properties which compare favourably with those of conventionally produced material.

The removal of internal porosity in copper, by B. Clapson and D. A. Robins (Research Laboratories, The General Electric Co. Ltd, Wembley).

Observations on the removal of internal porosity in copper have shown the importance of grain boundaries in the sintering process. Grain boundaries act as strong vacancy sinks in contrast to twin boundaries and dislocations, which apparently do not absorb a large number of vacancies. It is concluded that, in copper, the mechanism of sintering is that of the diffusion of vacancies to the grain boundaries, where they are destroyed by the progressive removal of planes of atoms adjacent to the boundaries.

The influence of van der Waals force on the sintering of glass, by R. Bullough and F. O. Jones (Research Laboratory, Associated Electrical Industries Ltd, Aldermaston, Berks.)

The contribution of van der Waals forces to the sintering of glass particles has been estimated. The contribution appears to be small relative to surface-tension forces in practical cases, but may be of importance in the formation of the initial bond during sintering.

The oxidation of hot-pressed titanium carbide and titanium boride in the temperature range 300–1 000° C, by N. F. Macdonald and C. E. Ransley (The British Aluminium Co. Ltd)

The oxidation characteristics of pure hot-pressed titanium carbide and titanium boride (TiB_2) have been studied in the range 300–1 000° C.

Titanium carbide shows a very marked peak in the rate of oxidation at ~ 450° C, the oxidation product at this temperature being anatase (TiO_2), which is powdery and non-adherent; the oxidation thus follows a linear law. Above ~ 700° C the rate increases rapidly again and is approximately parabolic. The scale in this case consists of a dense crystalline film of rutile.

The oxidation of the boride is less rapid than that of the carbide over the whole temperature range but it, too, shows a slight peak at 450° C. The oxidation tends to be parabolic at higher temperatures. The nature of the oxidation products has not been determined.

Preliminary studies on the evolution of fumes from iron at high temperatures

By E. T. Turkdogan and L. E. Leake

SYNOPSIS

Experiments have been carried out on 1-g and 900-g amounts of molten iron containing carbon. The metal was decarburized using oxygen, air, ferric oxide, or mixtures of oxygen–steam or oxygen–carbon dioxide. Microscopical and X-ray examinations of the fumes gave information about the physical and chemical conditions of the constituent particles. The results indicate that the fume evolution decreases with decreasing carbon content of the melt. Attempts have been made to explain the causes of fume formation by considering the available data on converter practice as well as those obtained from the present work. It appears that whilst direct vaporization of iron in the converter process is a possible explanation, the fume accompanying the reaction between iron oxides and carbon may be caused by an indirect vaporization of iron, i.e. by the formation of either an iron carbonyl or a volatile iron sub-oxide. 1671

INTRODUCTION

LITTLE FUNDAMENTAL WORK has been done to investigate the causes of fume formation at high temperatures in iron and steelmaking processes. Copious fumes are generally evolved during the conversion of hot metal to semi- or completely refined steel in the pneumatic processes; fumes are also evolved during certain stages of refining in electric-arc or open-hearth furnaces. It is a generally accepted view that the intensity of the fumes becomes greatest when commercially pure oxygen is used as the oxidizing medium.

When studying the mechanism of the reduction of metallic oxides, Schaller and Kohlmeyer[1] noted that during the reduction of iron oxides by carbon and the oxidation of iron–carbon melts by air or ferric oxide, volatilization of iron occurred. This observation was later studied in more detail by Kohlmeyer and Spandau,[2] who found that when iron–carbon melts were decarburized by blowing oxygen or air on the surface or by adding ferric oxide pellets, brown iron-oxide fumes were produced; the amount of fume evolved became noticeably less when the carbon content of the melt was below 2%. Similar experiments carried out with molten manganese or nickel containing carbon produced manganese oxide or nickel oxide fumes. In the light of their experimental results, Kohlmeyer and Spandau reached the conclusion that the evolution of fume was brought about by the formation of a complex iron carbonyl which decomposed to iron and carbon monoxide above the surface of the melt; these substances were then oxidized in air yielding iron oxide fumes and carbon dioxide; if air were excluded there was a deposit of grey iron.

Recently, Kosmider, Neuhaus, and Kratzenstein[3] put forward an entirely different explanation for this phenomenon. They suggested that during Bessemer refining of the hot metal by oxygen or air, the temperature of the metal at the tuyere tips is raised locally to very high values, perhaps up to about 3 000° C. At these temperatures the vapour pressure of iron is quite high and therefore a fair quantity of iron vapour may be carried to the surface and blown into the atmosphere where it is readily oxidized producing reddish brown fumes. Using the results

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Dr Turkdogan is Head of, and Mr Leake is a member of the Physical Chemistry Section of the Chemistry Department of BISRA.

of their measurements on a basic Bessemer converter, these authors calculated the temperature of the hot spots and obtained the following results:

(*a*) $t = 2\,300°$ C by refining with air
(*b*) $t = 2\,650°$ C by refining with oxygen-enriched air, i.e. 33% oxygen in the blast
(*c*) $t = 3\,050°$ C by blowing with oxygen.

In a detailed study of the chemistry of basic converter practice, Bogdandy and Pantke[4] obtained some useful data. Their measurements indicated that there was a rapid increase in fume emission during the last 2 min of blowing and that the fume consisted of finely subdivided metallic iron together with its oxides. They stated that the iron vapour formed at the gas–metal reaction zone, i.e. the hot spot, is carried through the bath by gas bubbles. During the early stages of blowing, the bath is stirred vigorously by the carbon boil and, as a result, condensed iron vapour dissolves in the bath before reaching the surface, and hence the absence of fumes.

Holden[5] studied some of the factors which affect the emission of iron oxide fumes from basic OH furnaces. His results indicate that the fumes become appreciable when the carbon content of the metal is high and when pitch creosote is used in place of fuel oil.

The experimental data so far available give some useful and interesting information on some of the steelmaking conditions which favour or hinder fume evolution. However, further detailed research is necessary before a definite theory can be put forward on the mechanism of fume formation at high temperatures. Experiments have been made to study some of the factors which might influence the extent of fume emission from molten iron and iron alloys: the results so far obtained will be discussed in this paper.

EXPERIMENTAL

Initial experiments were carried out on 1-g samples of alloyed iron melts. Then followed further experiments in which oxygen-bearing gases were blown on the surface of 900-g melts.

In these experiments, iron alloys were heated in oxygen-bearing gases and the fumes collected. The apparatus used for these experiments was very similar to that normally used for sulphur determinations by the combustion method. The reaction tube was fitted on one end with a glass end-piece to which was sealed an optical flat so that the contents of the reaction tube could be observed during the experiments. This end-piece was also provided with a side arm for connection to a gas-supply cylinder. The exit end of the reaction tube carried a removable filter consisting of a glass tube packed with glass wool. The outlet end of this filter was connected to a glass tube containing copper oxide at 500° C and then to a carbon dioxide absorption train. In some experiments, carbon monoxide was formed as a result of oxidation of the sample containing carbon; this was oxidized in the copper oxide furnace to carbon dioxide which in turn was determined by the absorption method. To recover all the fumes, a silica tube was inserted between the combustion boat and the glass-wool filter. The outside diameter of this tube, which served as a condenser, was slightly less than the bore of the reaction tube; this provided a comfortable sliding fit. The length of the condenser was adjusted so that one end extended to the fringe of the furnace hot zone and the other end protruded slightly from the cool end of the reaction tube. Most of the fumes were deposited on the inner wall of the condenser, whilst the remaining finer air-borne particles were trapped completely in the glass-wool filter.

In a typical experiment the procedure was as follows: the reaction tube and carbon dioxide absorption train were first flushed with nitrogen, the carbon dioxide absorption tube having been previously weighed. The glass wool was renewed and the combustion boat, containing 1 g of an iron alloy of known composition, was inserted into the hot zone of the furnace. The glass end-piece was then rapidly replaced. The sample was kept in an atmosphere of nitrogen for 5 min to allow the temperature of the boat and its contents to reach that of the furnace hot zone, i.e. 1 400° or 1 500° C. The flow of nitrogen was then stopped and the reacting gas, i.e. oxygen with or without other gases, was passed through the reaction chamber. At the end of a specified time interval, the flow of the reacting gas was stopped and the apparatus again purged with nitrogen. The condenser tube was then withdrawn from the furnace, and together with the filter, was immersed in hot 30% hydrochloric acid solution which was kept boiling for 15 min. The iron oxides collected in both the condenser and filter were estimated quantitatively as total iron. The amount of carbon removed from the sample was derived from the gain in weight of the carbon dioxide absorbent.

Throughout the experiments the total flow rate of the gases supplied to the furnace was 1 l./min. During the time of the reaction the true temperature of the melt might have been different from the initial temperature but no attempt was made to measure it.

Experiments with 900-g melts

In these experiments, iron–carbon alloys melted in a high-frequency furnace were surface-blown with oxygen, air, oxygen–steam mixtures, or carbon dioxide, and the fumes produced were collected by means of an apparatus shown diagrammatically in Fig. 1. The reacting gas was metered through the lance at a rate of 500 ml/min. The duration of each experiment depended to some extent upon the rate at which fume was deposited on the filter and varied from 3 to 11 min. At the end of the reaction time the gas flow was stopped and the cowls and filter removed. The oxide fume collected on the filter, together with any fume deposits that could be removed with a fine brush from the porcelain hood, were dissolved in boiling hydrochloric acid and estimated as total iron. Immediately before and after each experiment the temperature of the melt was measured with a dip thermocouple and the metal was sampled for carbon analysis.

On the same melt the above procedure was repeated several times with a view to observing the effect of the carbon content of the iron on the amount of fume produced.

The fumes collected were free of metallic splashes;

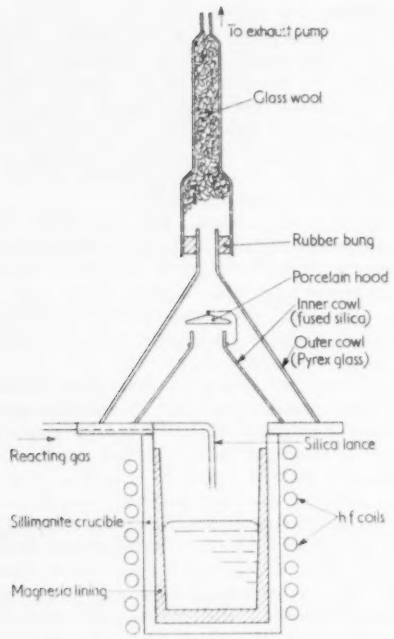

Fig. 1—Experimental apparatus

these were trapped almost entirely on the inner surface of the silica cowl and porcelain hood. Visual examination during and after the experiments indicated that only a small proportion of the fume was deposited on the inner surface of the silica cowl. No attempt was made to recover this fume deposit which was heavily contaminated with metal and slag splashes.

Materials

For experiments with 1-g samples, various pure alloys were prepared in a h.f. furnace and the melts were sucked into $\frac{1}{8}$-in. bore silica tubes and crushed as fine as possible. If the alloys were soft, turnings were obtainable. The composition of the alloys is given in Table I. The base metal was the high-purity BISRA iron and the other elements were of AR grade. For experiments with 900-g melts dead-mild steel was used.

In a number of experiments 1 g of iron–carbon alloys or pure graphite was mixed with 1 g of a flux and the mixture was used in the experiments. The fluxes initially prepared by fusion were those corresponding to the following formulæ: Fe_2SiO_4, $CaFe_2O_4$, and $CaSiO_3$; Fe_2O_3 was prepared by heating ferric sulphate.

RESULTS

Experiments with 1-g melts

When pure iron or its alloys with sulphur, nitrogen, phosphorus, silicon, or manganese were melted in a stream of oxygen (furnace temperature at 1 400° C) for 15 min, no detectable amount of fume was evolved. In experiments where the alloys in the combustion boat were covered with 1 g of ferric oxide, again no fume was evolved.

When iron–carbon alloys were heated in an oxidizing atmosphere, appreciable quantities of fume were evolved. In all cases oxidation of the sample was accompanied by fierce evolution of carbon monoxide which burned to carbon dioxide with a glow on the surface of the metal. Although there were metal splashes in the vicinity of the boat, the condenser tube was free of these splashes which were easily distinguishable from the condensed fume particles. When, on occasions, the condenser was contaminated with a few specks of iron oxide splashes, the experiment was discarded.

One of the interesting features of the experiments was that immediately after the introduction of oxygen into the furnace, the oxidation of carbon and evolution

TABLE I
Composition of alloys prepared

	Element, wt-%					
Base metal	**C**	**S**	**N**	**P**	**Si**	**Mn**
Iron	6·12					
,,	3·55					
,,	2·33					
,,	1·77					
,,	1·00					
,,		2·11				
,,		0·36				
,,			3·4			
,,				2·0		
,,					3·0	
,,						10·0
,,	0·10			2·0		
Nickel	1·66					
Cobalt	2·21					

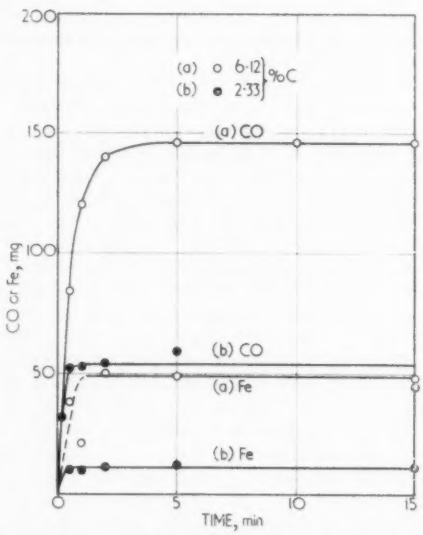

Fig. 2—Evolution of CO and Fe related to time of experiment (gas flow rate 1 l./min)

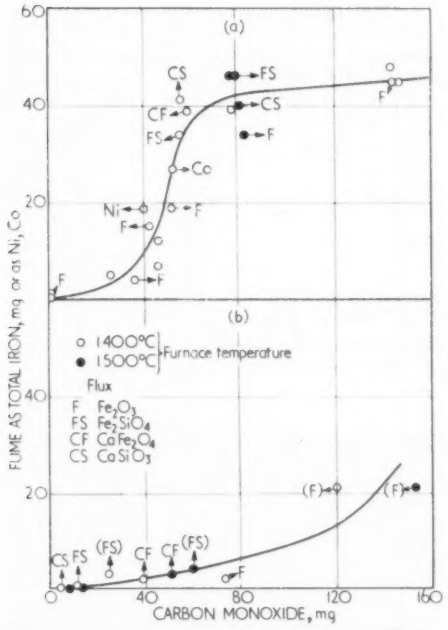

Fig. 3—Relationship between fume evolution and oxidation of carbon, (*a*) in oxygen, (*b*) in nitrogen using fluxes (gas flow rate 1 l./min)

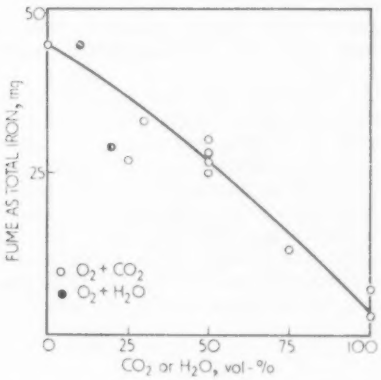

Fig. 4—Fume produced on melting 3·35% carbon–iron alloy in $O_2 + CO_2$ or $O_2 + H_2O$ atmosphere; initial melt temperature 1 400° C and weight of sample 1 g (gas flow rate 1 l./min)

of fume started. When the carbon–oxygen reaction ceased, there were no signs of fume evolution. To clarify this interesting observation a few time experiments were carried out with two of the iron–carbon alloys. As seen from the results in Fig. 2, in 2·33% carbon alloy, the amounts of fume evolved and carbon oxidized in 15 min were the same as those obtained within the first 15–30 s of the reaction. With the alloy containing 6·12%C the reaction was completed in 2–3 min. In all the subsequent experiments the reaction time was 15 min.

The results are given graphically in Fig. 3 where the fume measured as total iron is plotted against the total amount of carbon oxidized (converted to carbon monoxide). The symbols represent the type of flux used and those within brackets indicate that pure graphite was used in place of an iron–carbon alloy. The points without symbols are for those melts where flux was not used. Independent of the nature of the flux, there is a definite relationship between fume evolution and the amount of decarburization. The points in Fig. 3*a* for nickel–carbon and cobalt–carbon alloys are well in line with those obtained from the iron–carbon melts. When oxygen was replaced by nitrogen, there was a marked reduction in the amount of fume formed. An increase in the initial temperature of the melt from 1 400° to 1 500° C does not seem to influence the relationships in Figs. 3*a* and *b*.

In a few experiments the samples, containing 3·35%C, were heated in oxygen–carbon dioxide mixtures and fumes were collected as before. At the end of the reaction time, i.e. 15 min, the condenser and filter were removed rapidly and the reaction tube was connected to the carbon dioxide absorbent and pure oxygen was passed through the furnace. In this way it was possible to measure the percentage of the residual carbon. This was found to be negligible, indicating that irrespective of the gas composition almost all the carbon was oxidized in a 15-min reaction.

As seen from the results in Fig. 4, there is a continuous reduction in the amount of fume produced as the amount of carbon dioxide in the gas mixture increases. When oxygen was replaced completely by carbon dioxide, the amount of fume evolved from 1 g of 3·35%C alloy, i.e. 72 mg of CO from 1-g sample, was comparable with that produced by decarburizing the alloy with an iron oxide flux in a stream of nitrogen.

Three experiments were also carried out with oxygen containing 10%, 20%, or 30% steam. This was accomplished by bubbling oxygen through water at a given temperature. Initially, the temperature of the water bath was calibrated against the percentage of steam enrichment of the oxygen. The results given in Fig. 4 follow a pattern similar to that obtained with oxygen + carbon dioxide mixtures.

Experiments with 900-g melts

In these experiments the melts were surface blown with oxygen, air, carbon dioxide, or oxygen–steam mixtures and the results obtained are given in Table II. As seen from the results, the amount of fume produced decreased as the carbon content of the melt decreased. At carbon concentrations of 0·02%, the fume evolved was virtually nil. In melt E dead-mild steel containing about 0·02%C was used and again no fumes were produced after 10 min of blowing. In Figs. 5 and 6 the amounts of fume collected as total iron per minute of blowing are plotted against the mean carbon content of the melt during blowing. There is a clear indication that the fumes produced increase with increasing carbon content of the melt. Below about 2% carbon in the melt, there was an appreciable reduction in the amount of fume evolved. These observations are quite in line with those of Kohlmeyer and Spandau.[2] Figure 6 shows that the

introduction of steam into oxygen reduces markedly the amount of fume formed, and when the metal is decarburized with pure carbon dioxide very little fume is evolved.

It should be stated that the amount of the iron oxide particles deposited on the silica lance was somewhat greater in oxygen–steam blowings than with those using pure oxygen or air. It is possible, therefore, that some of the fume might have been agglomerated immediately above the surface of the melt when steam was blown along with oxygen. Although the results in Fig. 6 indicate an appreciable reduction in the amount of fume collected, it is not yet certain that the introduction of steam lowers the fume actually generated.

TABLE II

Results of experiments with 900-g melts

Melt no.	Expt. no.	Starting temp., °C	Finishing temp., °C	%C at start	%C at finish	Time of blowing, min	Fume as total Fe, g
			O_2 blowing on surface				
A	1	1481	1510	3·46	2·89	10	1·035
	2	1453*	1495	2·89	2·19	10	0·377
C	1	1460	1538	3·76	3·52	3·5	0·782
	2	1538	1547	3·52	3·26	3	0·781
	3	1547	1550	3·26	3·06	3	0·337
	4	1550	1560	3·06	2·68	4	0·628
	5	1544	1575	2·33	2·15	7	0·112
	6	1575	1611	2·15	1·74	7	0·064
	7	1611	1607	1·74	1·14	10	0·030
D	1	1538	1545	0·98	0·39	10	0·058
	2	1545	1545	0·16	0·05	10	0·007
	3	1545	—	0·05	0·03	10	0·008
	4	—	—	0·03	0·02	10	0·003
	5	—	—	0·02	0·02	10	0·001
	6	—	—	0·02	0·02	10	0·001
E	1					10	0·001
			Air blowing on surface				
F	1	1474	1505	3·40	3·16	7	0·780
	2	1505	1531	3·16	2·88	7	1·054
	3	1531	1538	2·88	2·66	7	0·789
	4	1538	1545	2·66	2·34	8	0·639
	5	1545	1570	2·34	2·04	8	0·084
	6	1570	1575	2·04	1·82	8	0·044
G	1	1538	1574	2·22	2·07	11	0·765
	2	1574	1596	2·07	1·88	9	0·187
	3	1596	1600	1·88	1·67	11	0·040
	4	1600	1603	1·67	1·48	10	0·042
	5	1603	1614	1·48	1·03	11	0·044
	6	1614	1605	1·03	0·90	11	0·044
	7	1605	1586	0·90	0·56	11	0·026
	8	1586	1585	0·56	0·29	11	0·016
			CO_2 blowing on surface				
H	1	1495	1495	2·57	2·49	10	0·004
	2	1495	1481	2·49	2·46	10	0·002
	3	1481	1476	2·46	2·32	10	0·002
	4	1476	1439	2·32	2·10	10	0·002
			50% O_2 + 50% H_2O vapour blowing on surface				
J	1	1488	1495	3·96	3·57	10	1·679
	2	1495	1574	3·57	3·07	10	0·743
	3	1574	1625	3·07	2·40	10	0·203
	4	1442*	1531	1·55	0·69	7	0·044
	5	1531	1567	0·69	0·04	10	0·007
	6	1567	—	0·04	0·02	10	0·001
			70% O_2 + 30% H_2O vapour blowing on surface				
K	1	1460	1464	3·42	2·90	10	0·919
	2	1464	1464	2·90	2·41	10	0·321
			90% O_2 + 10% H_2O vapour blowing on surface				
L	1	1488	1517	3·60	3·14	10	1·386
	2	1517	1567	3·14	2·65	10	1·376
	3	1567	1599	2·65	2·28	10	0·037
	4	1599	1617	2·28	1·75	9	0·032
	5	1617	1581*	1·75	1·17	10	0·014
	6	1581	1580	1·17	0·52	10	0·009

* Temperature lowered intentionally

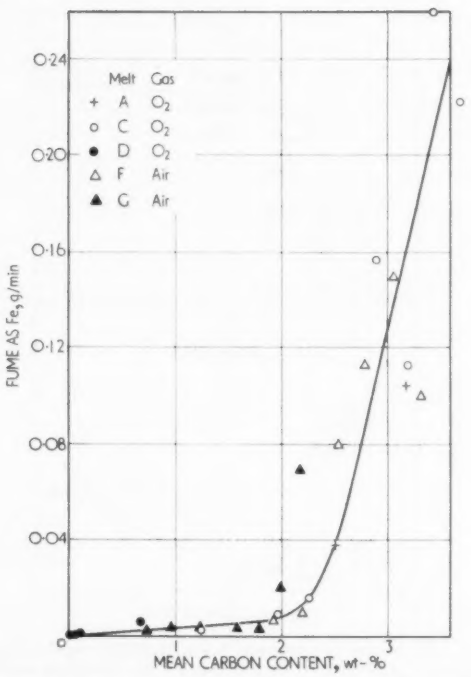

Fig. 5—Fume as total iron related to mean carbon content of 900-g melt (gas flow rate 500 ml/min)

From the results in Table I it will be seen that there is a marked increase in the temperature of the melt during the early stages of blowing. In some heats the increase in temperature during 20–30 min blowing was about 120° C. Owing to the design of the apparatus heat losses were high and no correlation could therefore be found between the temperature of the melt and blowing time. In series H, where carbon dioxide was the reacting gas, a slight reduction in temperature was observed.

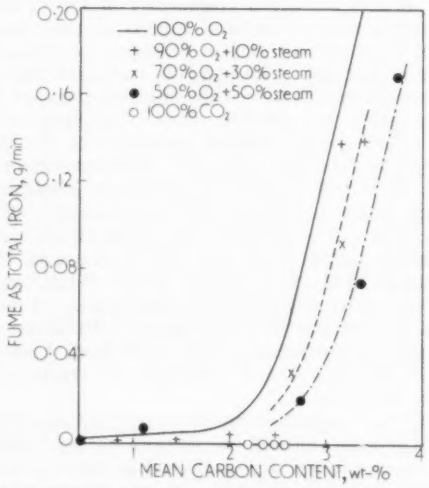

Fig. 6—Fume as total iron related to the mean carbon content of 900-g melt (gas flow rate 500 ml/min)

TABLE III—Use of oxygen

Melt no.	Expt. no.	O_2 blown, l.	O_2 consumed, l.
A	1	5·00	4·79
C	1	1·75	2·02
C	3	1·50	1·68
C	7	5·00	5·04
F	6	0·84	1·85
G	4	1·05	2·28

In many experiments the amount of oxygen consumed in the oxidation of the carbon to carbon monoxide was much higher than that blown on to the metal, as will be seen from the few examples in Table III.

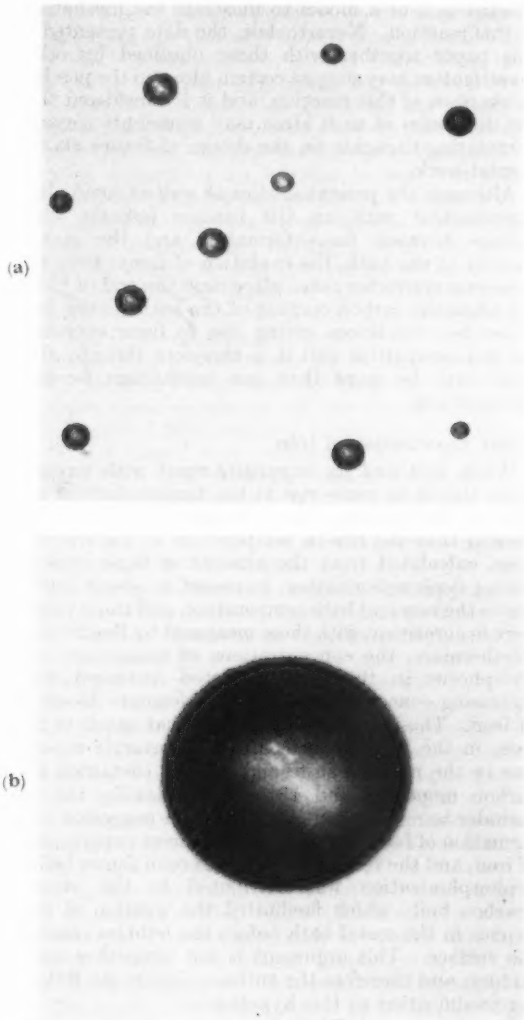

Fig. 7—Photomicrographs of fumes produced during decarburization of molten iron by ferric oxide in nitrogen, (*a*) × 600, (*b*) × 3 000

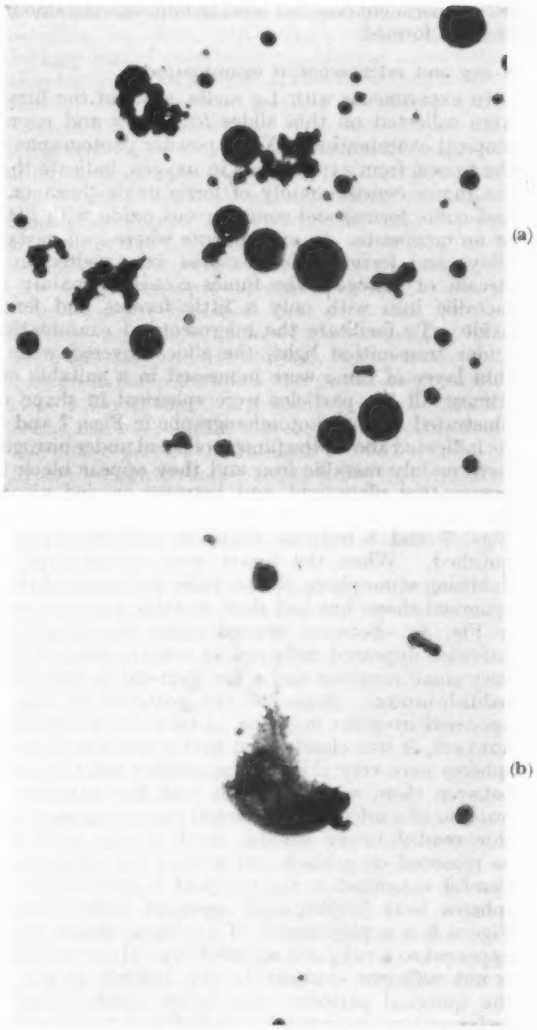

Fig. 8—Photomicrographs of fumes produced during decarburization of molten iron by oxygen × 600

The furnace assembly was not gas-tight, and therefore, although nitrogen was blown into the crucible during the melting of the charge, it was not possible to avoid oxidation of the metal, and by the time the charge was molten the surface of the crucible in contact with the metal was saturated with iron oxides. Therefore, during decarburization, the carbon must have acquired some of the oxygen from this oxide layer. This is quite a common occurrence in practice where, during the early stages of oxygen blowing, the iron oxide content of the slag increases and, as the rate of decarburization increases at the later stages of blowing, there is a marked reduction in the iron oxide concentration of the slag.

Although these experiments clearly indicate that decarburization is accompanied by fume evolution, the rate or the amount of carbon oxidized during

each experiment does not seem to influence the amount of fume formed.

X-ray and microscopical examination

In experiments with 1-g melts, some of the fumes were collected on thin slides for X-ray and microscopical examination. X-ray powder photographs of the fumes, from experiments in oxygen, indicate that the fumes consist mainly of ferric oxide (hexagonal and cubic forms) and some ferrous oxide with little or no magnetite. In experiments where iron–carbon alloys and ferric oxide mixtures were melted in a stream of nitrogen, the fumes consisted mainly of metallic iron with only a little ferrous and ferric oxide. To facilitate the microscopical examination under transmitted light, the slides covered with a thin layer of fume were immersed in a suitable oil. Almost all the particles were spherical in shape as illustrated by the photomicrographs in Figs. 7 and 8. As indicated above, the fumes collected under nitrogen were mainly metallic iron and they appear black in transmitted plain-light and between crossed nicols. Strong light reflections seen on these particles in Figs. 7 and 8 indicate that the surfaces are well polished. When the fumes were collected in an oxidizing atmosphere, the particles still retained their spherical shape but lost their metallic lustre as seen in Fig. 8. Between crossed nicols almost all the particles appeared ruby red in colour; some of the very small particles and a few thin flakes were light reddish-brown. Some of the particles in Fig. 8 appeared irregular in shape. Under the microscope, however, it was clearly seen that a number of small spheres were very close to one another and the space between them was filled with very fine particles (a fraction of a micron in diameter) appearing more like thin reddish-brown clouds. Such details could not be recorded on a black and white photomicrograph. Careful examination showed that a number of the spheres were broken and appeared hollow inside. Figure 8 is a photograph of a broken sphere which appeared as a ruby-red coloured cup. However, there is not sufficient evidence to say whether or not all the spherical particles were hollow inside. This is an interesting observation, and further detailed studies on the shapes of the fume particles may yield constructive information.

The diameters of the spheres observed range from 1 to 14μ; the diameter of the sphere in Fig. 7 was about 14μ. Much finer particles were clustered together and their sizes could not be measured with an ordinary microscope.

DISCUSSION

The results obtained from the small and large-scale experiments indicate beyond doubt that the evolution of iron-oxide fumes accompanies the oxidation of carbon in molten iron. A few experiments showed that the same statement may apply equally well to cobalt–carbon and nickel–carbon melts, the fumes produced being cobalt or nickel oxide respectively. Another general conclusion is that when the oxidation of carbon is exothermic (with oxygen or in an oxidizing atmosphere), the fumes produced are appreciably larger in quantity than those produced by endothermic interaction with ferric oxide, although fume is still produced under these conditions.

The results of the experiments with 900 g of metal indicate that although the rate of decarburization does not seem to influence the amount of fume formation, there is a definite relationship between the carbon content of the melt and the quantity of fume emitted. It was also observed that during the decarburization of iron containing more than about 2·0%C, the bubbles breaking on the surface were very small, and numerous sparks were thrown out. At lower carbon concentrations, however, the bubbles on the surface of the melt were very much larger in size as also were the particles of metal and slag thrown out of the bath.

The results so far obtained classify broadly the conditions which may give rise to the formation of fumes; they do not, however, provide direct evidence for the construction of a model to illustrate the mechanism of this reaction. Nevertheless, the data presented in this paper together with those obtained by other investigators may suggest certain ideas on the possible mechanism of this reaction, and it is considered that the discussion of such ideas may contribute towards stimulating thoughts on the design of future experimental work.

Although the present studies as well as some plant experiments[5] with an OH furnace indicate some linkage between fume formation and the carbon content of the bath, the evolution of fumes from the Bessemer converter takes place near the end of blowing when the carbon content of the bath is very low. These two conditions giving rise to fume evolution are not compatible and it is therefore thought that there may be more than one mechanism for this phenomenon.

Direct vaporization of iron

When iron and its impurities react with oxygen, there should be some rise in the temperature of the melt at the reaction zone. Bogdandy and Pantke[4] showed that the rise in temperature at the reaction zone, calculated from the amount of fume evolved during dephosphorization, increased to about 500° C above the nominal bath temperature, and these values were in agreement with those measured by Bogdandy.[6] Furthermore, the concentrations of manganese and phosphorus in the fume collected increased with increasing concentrations of these elements dissolved in iron. These authors also found that much of the iron, in the fume collected in the converter mouth, was in the metallic state and the gas contained 4% carbon monoxide and 1% carbon dioxide, the remainder being nitrogen. These authors suggested that formation of fume was the result of direct vaporization of iron, and the reason for the absence of fumes before dephosphorization was attributed to the violent 'carbon boil' which facilitated the solution of iron vapour in the metal bath before the bubbles reached the surface. This argument is not altogether satisfactory, and therefore the authors suggest the following modification to this hypothesis.

On a larger production plant, iron and its impurities will be oxidized at the tuyere level by the incoming air, the temperature of the reaction zone will be

increased and some of the metal could vaporize. Gas bubbles which rise through the bath could be surrounded by a liquid iron oxide-rich slag envelope and probably contain vapour phase in the form of mist. In a deep bath this envelope could be broken by the reducing action of carbon and any iron mist in the bubbles would therefore come into direct contact with the metal and dissolve in the bath. At the end of carbon removal, however, the liquid iron oxide envelope around the gas bubbles could remain unreduced, and therefore the iron mist contained in these bubbles would pass through the bath and be discharged as fume. If this is the mechanism, three major conditions could influence its control: (i) a high temperature at the tuyere level, (ii) the coating of bubbles by an iron oxide film, and (iii) a carrier gas ascending rapidly through the bath.

Although the same mechanism may apply to both acid and basic converter practices, in the basic process the oxidation of phosphorus and iron will raise the 'hot spot' temperature to a level higher than that obtained by oxidizing iron alone, and therefore fume formation will increase. As shown by the results of Kosmider *et al.*[3] and Bogdandy and Pantke,[4] enrichment of air with oxygen increases the formation of fume as a result of an increase in the 'hot spot' temperature. Another interesting observation is that with oxygen-enriched blast some fume is evolved even during decarburization. Bearing in mind the mechanism discussed, it may be suggested that with oxygen-enrichment, some of the bubbles rising through the bath may retain their iron oxide coating even during decarburization.

Attempts to reproduce the above three conditions in the laboratory melts have not been successful. For example, when oxygen or air was blown into or on the surface of 900 g of iron containing 0·1%C and 2%P, no fumes were evolved. Any conclusions reached from this particular laboratory experiment cannot obviously be related to actual converter practice.

Indirect vaporization of iron

Consider again the experiments of Kohlmeyer *et al.*[1] and those of the authors: there is clear evidence that when carbon (dissolved in iron or in free graphite form) is oxidized by iron oxides in a neutral or an oxidizing atmosphere, fumes are evolved.

In this case direct vaporization of iron is not possible, because (i) the reaction is endothermic, and (ii) at temperatures below 1 600° C, where decarburization was carried out, the vapour pressure of iron is quite low. Since the system consists of iron, carbon, and oxygen, the only conclusion to be reached is that a volatile iron compound of the type $Fe(CO)_5$ or Fe_xO must be formed.

A fair amount is known about the properties of iron carbonyl, $Fe(CO)_5$. At 25° C its heat of formation from iron and carbon monoxide is — 54·0 Kcal/mole and its melting and boiling points are — 21° and 105° C, respectively.[7] This compound decomposes readily at elevated temperatures, and it appears most unlikely that it can form at steelmaking temperatures. In fact, when carbon monoxide was bubbled through iron–carbon melts, no fumes were observed.

A number of elements are known to form volatile sub-oxides, e.g. SiO, Al_2O, Zr_2O. In fact many refractory oxides deteriorate on heating in reducing atmospheres by the formation of volatile sub-oxides. Similarly, some elements also form sub-halides which have high vapour pressures. For example, Russell, Martin, and Cochran[8] showed that when aluminium trichloride vapour was passed over metallic aluminium at 800° C and 0·001 atmosphere pressure, aluminium monochloride vapour could be formed, and at lower temperatures the monochloride disproportionated to yield metallic aluminium and the trichloride. Recently, some interesting experiments were carried out by Lee[9] on the transportation of metals by the formation and subsequent disproportion of the volatile sub-halides. He showed, for instance, that when ferrous chloride vapour was passed over metallic iron at 1 300° C and 2·3 mm Hg pressure, metallic iron and ferrous chloride were deposited on the walls of the cooler part of the furnace.

From these statements it appears that the formation of a volatile iron sub-oxide is within the realm of possibility. If such an oxide is formed, it will disproportionate at lower temperatures to yield iron and iron oxides.

If the formation and subsequent disproportionating of a volatile iron oxide is the means for the indirect vaporization of iron, it should in theory be possible to achieve this by reacting iron oxides with reducing agents other than carbon, provided the physical conditions in the melt make the formation of gas bubbles possible. In this respect, carbon may perform an important additional role by forming carbon monoxide bubbles into which volatile iron oxide could diffuse. From these considerations it follows that detailed work should be carried out to discover whether or not a volatile iron oxide or an iron carbonyl exists at steelmaking temperatures and oxygen potentials.

Unlike conventional converter practice, in top-blown oxygen processes the oxidation of iron takes place before and during decarburization and it is therefore plausible that fume formation may take place by direct as well as indirect vaporization of iron.

CONCLUSIONS

The experimental results indicate that decarburization of iron is accompanied by the emission of iron oxide fumes, and this decreases with decreasing carbon content of the melt. If oxygen is diluted by steam or carbon dioxide, or if decarburization is carried out by iron oxides, less fume is produced. Under laboratory conditions, the reaction of carbon-free iron or iron alloys with oxygen did not produce fumes.

Considering the available data on converter practice, it appears that direct vaporization of iron is a possible explanation of fume emission. The fact that this happens after the removal of carbon may be due to the retention of the iron oxide film around the gas bubbles where the iron mist is entrapped.

When iron oxides react with carbon, fume is formed in spite of the fact that the reaction is endothermic. It therefore appears that an indirect vaporization of iron may be the mechanism of fume formation when decarburization of iron is brought about by iron oxides. This could involve the formation of a volatile

iron carbonyl or even a volatile lower iron oxide.

The mechanism of fume emission applicable to top-blown oxygen processes may be a combination of direct as well as indirect vaporization of iron.

ADDENDUM

At the time this paper was written the authors became aware of a paper by Son-Chol and Abrosimov[10] who had investigated the fume evolution from an OH furnace by sampling the gases in the slag pocket, in the gas-checkers, and in the flues. They found that whilst the fume collected in the slag pocket during melt down was about 1·0 g/m^{-3}, immediately after the hot metal addition fume emission increased to about 12 g/m^{-3} and during refining it remained at about 0·7 g/m^{-3}. When oxygen was blown into the metal, the fume in the slag pocket rose to 24 to 34 g/m^{-3}. When a steam–oxygen mixture (1·3 : 1) was blown, the fume emitted was reduced by a factor of five. They observed that the average fume particle size was 0·7–0·07μ. The findings of Son-Chol and Abrosimov are in accord with those of Holden[5] and give additional evidence in support of the arguments presented in this paper.

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Letter to the Editor: χ phase in the Fe–Cr–Ni–Ti system

SINCE the occurrence of a phase designated χ was first reported[1] a number of papers have described its occurrence in Fe–Cr–Mo alloys[2–4] and Fe–Cr–Mo–Ti alloys.[5, 6] Kasper[7] studied its structure using both X-ray and neutron diffraction. It was found to be an ordered α–Mn type. Although Ver Snyder and Beattie[5] and Koch and Ilschner-Gensch[6] found that Ti seems to promote the formation of χ, as far as the writers are aware Mo has always been present in iron alloys where χ phase occurs with one exception. Kuo in the discussion to Ver Snyder and Beattie's paper reports finding an analagous phase in the Fe–Cr–W ternary.

During an investigation into the properties of an Fe–Cr–Ni–Ti alloy (analysis 0·026%C 0·54%Mn 0·42%Si 4·10%Ni 24·90%Cr 3·48%Ti 0·037%Al) we have encountered a phase with the same X-ray pattern as χ phase and αMn. There are, however, certain differences in line intensities, these are listed in Table I together with the interplanar spacings (a = 8·838kX) and indices of the phase. A residue (which was completely χ phase) obtained from a specimen heat treated at 850° C for 120 h was sufficiently abundant to give a reasonably accurate chemical analysis. This indicated that the χ phase might be allocated a formula $Fe_{35}Cr_{13}Ni_9Ti_7$ compared with $Fe_{32}Cr_{16}Mo_{10}$ after Andrews and $Fe_{36}Cr_{12}Mo_{10}$ used by Kasper in his work, i.e. the replacement of Mo atoms primarily by Ti atoms.

TABLE I

X-ray data for Fe–Cr–Ni–Ti χ phase
(a = 8·838kX)

Intensity of Fe–Cr–Ni–Mo χ	Intensity of Fe–Cr–Ni–Ti χ	$h^2 + k^2 + l^2$	Corrected *d*
w	...	...	...
vw	vw	16	2·210
s	s	18	2·083
m	m	22	1·884
wm	w	24	1·804
w	wm	26	1·733
w	...	...	...
wm	vvw	38	1·434
w	vw	44	1·332
w	w	48	1·276
wm	wm	50	1·250
ms	ms	54	1·203
vvw	w	56	1·181
vvw	vw	58	1·160
wm	wm	62	1·122
vw	vw	66	1·088
w	vw	68	1·072
vw	vw	70	1·056
m	m	72	1·042
wm	w	74	1·027
vw	vw	76	1·014
vw	vw	78	1·001
wm	wm	82	0·9760
vw	vvw	84	0·9643
w	wm	86	0·9530
wm	w	88	0·9421
m	m	90	0·9316
wm	w	94	0·9116

It is intended to attempt to improve the quaternary Fe–Cr–Ni–Ti composition to give a pure χ phase. It would also be interesting to find out whether the presence of Ni is essential.

The results obtained, however, establish that χ phase can occur in alloy steels containing titanium without molybdenum. In other cases reported so far the presence of molybdenum had apparently been decisive in leading to its formation rather than other constituents.

H. Hughes
D. T. Llewelyn

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Research and Development Department

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N E W S

Announcements and News of Science and Industry

THE IRON AND STEEL INSTITUTE

President's announcements at Annual General Meeting

At the Annual General Meeting of the Institute, held at Church House, Westminster, on Wednesday, 6th May, the President, Mr C. R. Wheeler, C.B.E., made the following announcements.

Increase in subscription rates

He said that the Council had reluctantly decided that it was necessary to ask Members to agree to an increase in subscription rates. The present rates had been in force since 1st January, 1949. The following resolutions were put to the Meeting, and were carried unanimously:

1. That as from the 1st January, 1960, the annual subscription payable by ordinary members be increased to £5 5*s*. 0*d*. and the annual subscription payable by associate members whose age exceeds 25 years be £3 3*s*. 0*d*.

2. That as from the 1st January, 1960, any ordinary member whose subscription is not in arrear may at any time before the 30th June in any year, or if elected after that date in the year, within one month of his election, compound for his subscription for subsequent years on payment according to the following scale:

Up to 29 years of age	£88
From 30 to 39 years of age	£79
„ 40 „ 49 „ „ „	£70
„ 50 „ 59 „ „ „	£61
„ 60 years of age and upwards	£52

Provided that the passing of this Resolution shall not prejudice the validity of any composition duly effected according to the scale set out in Bye-Law 21 of the Institute's Bye-Laws.

The President stated that it was the intention of the Council to amend the regulations for Associate Membership, so that:

(*a*) the maximum age for Associate Members was increased from 25 to 28

(*b*) Associate Members up to the age of 25 would continue to pay a subscription at the reduced annual rate of £1 15*s*. 0*d*.

Members and Associate Members who were also Members of The Institute of Metals or of The Institution of Metallurgists or of an Affiliated Local Society or of a Kindred Society overseas would as at present be entitled to a reduction in subscription of 4*s*. a year up to the age of 25 and of 10*s*. 6*d*. a year if over 25 years of age.

The effect of these measures would be that as from 1st January, 1960, there would be no change in the subscriptions payable by those whose age did not exceed 25, that the subscription of those between the ages of 25 and 28 would be £1 1*s*. 0*d*. a year less, and that the subscription of those over the age of 28 would be £1 1*s*. 0*d*. more, than at present.

The proposed subscriptions payable from 1st January, 1960, are as follows:

	Standard rate		*Reduced rate**	
	Present	*Proposed*	*Present*	*Proposed*
Ordinary Members	£4 4 0	£5 5 0	£3 13 6	£4 14 6
*Associate Members**				
up to 25 years of age	£1 15 0	No change	£1 11 0	No change
over 25 and up to 28 years of age	£4 4 0†	£3 3 0	£3 13 6	£2 12 6

* Payable by those who are also Members of one of the Societies referred to above.
† Ordinary Member's rate.

Members whose age does not exceed 28 will be able to revert to the class of Associate Members if they so wish.

Members and Associate Members who are assessable to United Kingdom Income Tax under Schedule E are reminded that they can now claim relief of tax in respect of their subscriptions.

Special Meeting in the USA

The President said that the Council had given a good deal of thought to the possibility of holding a meeting in the United States of America. They were all agreed that it was most desirable from many points of view that the Institute should hold a meeting there. Accordingly it was with very real pleasure that he announced that an invitation had been received from the Metallurgical Society of AIME (The American Institute of Mining, Metallurgical, and Petroleum Engineers). The Secretary had written on 31st March, 1959:

> "As directed by the Board of Directors of the Metallurgical Society of AIME, I have been authorized to extend to The Iron and Steel Institute a cordial invitation to hold a Joint Meeting with our organization in the fall of 1961. We sincerely hope that this invitation will meet with acceptance by the Council of The Iron and Steel Institute."

That invitation had been accepted.

The Institute had close and friendly relations also with other societies in the United States. They hoped that some of these would be associated with the meeting. The Secretary of the American Iron and Steel Institute had said that that important organization "will be very happy to assist in making the arrangements for plant and laboratory visits." He had offered also to participate in the planning of the technical programme. That was most satisfactory.

The Council hoped that before long arrangements would also have been made for participation by the American Society for Metals.

This was only a preliminary intimation, but the Council thought it would be helpful for Members to know well in advance that arrangements were in hand for a meeting of the Institute in the USA in the autumn of 1961.

He was sure that Members would wish to join with him in expressing appreciation to their American friends for their initiative in issuing their cordial invitation.

The President added that Mr Barr and he had accepted invitations to attend the meeting of the American Iron and Steel Institute which was to be held in New York later in May.

Staff changes

The President announced that the Council had, on the recommendation of the Secretary, approved the following changes in staff appointments:

Mr **A. J. Post**, at present Assistant Secretary, to be Deputy Secretary.

Mr **H. F. Cleere**, at present Production Editor, to be Assistant Secretary and Executive Editor. In the latter capacity he remained responsible to Mr E. R. Mort, Managing Editor.

Mr **R. J. D. Harvey**, at present an Assistant Editor, to be Production Editor.

Special Meeting on the North-East Coast

The Institute is holding a Special Meeting on the North-East Coast from Monday to Friday, **6th to 10th July**, by invitation of companies in the district.

Details of the meeting, together with reply forms, have already been circulated to Members. The following is the outline programme:

Monday, 6th July

Members and Ladies — Arrive in the North-East Coast area.

Tuesday, 7th July

Members — All-day visit to the Cleveland and Lackenby Works of Dorman Long (Steel) Ltd., with lunch at Lackenby. Members will visit Eston Wharf, the ore-preparation and sinter plant, the South Bank coke ovens and the Clay Lane blast-furnaces (all at the Cleveland Works) and the steel plant and rolling mills, including the universal beam mill, at Lackenby.

Ladies — All-day motor-coach excursion in Cleveland, including a visit to Rievaulx Abbey with lunch.

EVENING

Members and Ladies — Reception and buffet supper at the Spa Pavilion, Saltburn. Members and Ladies will be the guests of Dorman Long and Co. Ltd., throughout the day and evening.

Wednesday, 8th July

Members — All-day visit to South Durham Steel and Iron Co. Ltd., with lunch and tea. Members will visit the works at West Hartlepool, including the South Plant under construction, in the morning and the Malleable Works at Stockton, including the 40-ft pipe plant, in the afternoon.

Ladies — All-day motor-coach excursion to Harrogate with lunch and tea.

EVENING

Members and Ladies Reception and supper at South Works, West Hartlepool.
Members and Ladies will be the guests of the South Durham Steel and Iron Co. Ltd. throughout the day and evening.

Thursday, 9th July

Members and Ladies

MORNING Travel by motor-coach via Rushyford or Durham to Lambton Castle, near Chester-le-Street.

AFTERNOON

Members Visit to the Consett Works of the Consett Iron Co. Ltd.

Ladies Motor-coach excursion to the Roman Wall.

EVENING

Members and Ladies Reception and dinner in the Assembly Rooms, Newcastle-upon-Tyne.
Members and Ladies will be the guests of the Consett Iron Co. Ltd. throughout the day and evening.

Friday, 10th July

MORNING

Members Visits to one of the following works:
- Stockton Works of Ashmore, Benson, Pease and Co.
- Thornaby and Middlesbrough Works of Head Wrightson and Co. Ltd.
- Skinningrove Works of the Skinningrove Iron Co. Ltd.

Ladies Morning free

END OF MEETING

NEWS OF MEMBERS

Mr **W. R. Beswick** has retired from the board of the Power-Gas Corporation Ltd.

Mr **A. J. Blackwell** has been appointed technical manager of the Vulcan Foundry of Gardshaw Ltd., Eckington, near Sheffield.

Mr **R. M. Chapman** has left K & L Steelfounders and Engineers Ltd. to become Lecturer in Industrial Metallurgy at Loughborough College of Technology.

Mr **S. G. Cope** has been awarded the degree of Ph.D. by London University.

Mr **H. E. Dixon,** formerly chief metallurgist to Atomic Power Constructions Ltd., has been appointed head of research and development and head of laboratories, Heston.

Mr **George Foster** has been appointed a special director of Dorman Long and Co. Ltd. and Dorman Long (Steel) Ltd.

Mr **A. G. Gilbertson** has been appointed director of the Brown, Lenox group of companies and chairman of Brown, Lenox and Co. (London) Ltd.

The **Earl of Halsbury** has joined the board of Head Wrightson Processes Ltd.

Mr **D. W. Hammond** has retired from the position of works director of William Jessop and Sons Ltd. and J. J. Saville and Co. Ltd., but he will remain on the board of the new company, Jessop-Saville Ltd.

Mr **E. J. Hancock** is now in business as a blast-furnace consultant.

Mr **C. E. Holmstrom** has joined the board of John Bedford and Sons Ltd.

Mr **G. J. T. Hume** has been awarded the degree of Ph.D. and the Diploma of Imperial College.

Mr **D. C. F. Lunn,** formerly deputy chief metallurgist, is now chief metallurgist to Atomic Power Constructions Ltd.

Mr **J. H. Osborn** has been awarded a diploma by the Institute of British Foundrymen in recognition of his part-authorship of a paper entitled "*A modern foundry for the manufacture of small steel castings by new moulding techniques.*"

Mr **T. E. Peacock** has been awarded the degree of Ph.D. by Durham University.

Dr **L. B. Pfeil,** F.R.S., has been elected a Fellow of the Imperial College of Science and Technology.

Mr **F. H. Poole** has been appointed joint managing director of Eva Brothers Ltd. with the chairman, Mr V. W. Eva.

Sir William Scott has been elected an ordinary member of council of the North East Coast Institution of Engineers and Shipbuilders.

Mr **E. J. C. Smith** has been appointed a local director of Rhodesian Alloys (Private) Ltd.

Mr **A. P. T. Taylor-Gill** has left Edgar Allen and Co. Ltd. to join Canatlas Steels (England) Ltd.

Mr **O. J. Thomas** has joined the Tinplate Division of the Steel Company of Wales Ltd.

Mr **F. H. Towler** has relinquished his position as managing director of Towler Brothers (Patents) Ltd. in order to concentrate on the development of new and improved hydraulic products; he will remain vice-chairman of the company.

Dr **J. F. Watkinson** has relinquished his position as Head of the Metallurgy Division of the B.S.A. Group Research Centre to become general manager and a director of B.S.A. Metal Powders Ltd., a newly formed subsidiary within the B.S.A. Group.

Dr **J. Wilcock** recently left the Department of Industrial Metallurgy, University of Birmingham, to join Powder Metallurgy Ltd.

Obituary

Mr **Gaston Henry Gilbert** (*elected* 1946), of Swansea, in March, 1959.

Mr **Joseph Richard Greenwood** (*elected* 1936), of Stockport, in March, 1959.

Mr **William Killingbeck** (*elected* 1955), of Barrow-in-Furness, on 25th March, 1959.

Sir **William James Larke,** K.B.E., D.SC., M.I.MECH.E., M.I.E.E. (*elected* 1904; *Honorary Vice-President* 1946; *Bessemer Gold Medallist* 1947; *Honorary Member* 1955), of London, on 29th April, 1959.

CONTRIBUTORS TO THE JOURNAL

O. Cuscoleca, DIPL.ING.—Technical Director Oesterreichisch-Alpine Montangesellschaft, Vienna and Leoben, Austria.

O. Cuscoleca

Otwin Cuscoleca was born in Vienna in 1905 and educated at the Montanistische Hochschule, Leoben, and the Technische Hochschule, Aachen. He qualified as a metallurgical engineer in 1931, and joined Vereinigte Stahlwerke, Niederrhein works. In the following year, he transferred to the August Thyssen works of the same company at Hamborn, staying there until 1939, when he joined Edelstahlwerk Schmidt und Clemens at Frankfurt-am-Main. From 1941 to 1945 he was with Hugo Schneider AG at Leipzig, and he joined his present company in 1945.

Mr Cuscoleca, who received the Hunt Award of the AIME in 1954, is the author of many technical papers, most of them concerned with oxygen steelmaking in the L–D converter.

S. Garber. B.ENG.(MET.), PH.D.—Principal Scientific Officer, Mechanical Working Division, British Iron and Steel Research Association, Sheffield.

S. Garber

Sidney Garber was born in Middlesbrough in 1923; his family migrated to Canada in 1929. He received his secondary education at West Hill High School, Montreal. In 1944 he graduated from McGill University with the degree of Bachelor of Engineering in Metallurgy. After six years in steel and iron foundries, he returned to England to carry out research in the Department of Metallurgy at Sheffield University. During this period he was awarded an Andrew Carnegie Research Scholarship by The Iron and Steel Institute. He obtained the degree of Ph.D. in 1954 for his work on the effect of sulphur, selenium, and tellurium on the graphite morphology in Fe–C–Si alloys.

After spending a year in Canada, Dr Garber returned to England and joined BISRA. He is at present responsible for the work of the Flat Rolled Products Research Team in the Mechanical Working Division. He is also Secretary of the International Deep Drawing Research Group.

V. Harrison—Manager, Medium Section Mill, Cleveland Works, Dorman Long (Steel) Ltd.

V. Harrison

Mr Harrison was born in 1927 and educated at St Joseph's College, Dumfries. He joined Dorman Long in 1943 as an engineering apprentice, and studied at the Constantine Technical College, Middlesbrough, obtaining the Higher National Diploma in mechanical engineering. After eight years as assistant manager of various mills within the company, he was appointed first manager of the new medium section mill in 1957.

V. Stephenson—Development Engineer-Central Engineering Department, Dorman Long (Steel) Ltd.

V. Stephenson

Mr Stephenson was born in 1926 and educated at the Robert Atkinson school, Thornaby-on-Tees. He joined Dorman Long in 1942 as an engineering apprentice, and obtained the Higher National Diploma in mechanical engineering after studying at the Constantine Technical College, Middlesbrough. After service in the drawing office and

project department on rolling-mill developments, he was appointed a development engineer in 1958.

J. H. Gittus, B.SC., A.I.M.—Leader of Foundry Group, Mond Nickel Co. Ltd., D. and R. Department Laboratory.

Mr Gittus, who was formerly an investigator at the British Cast Iron Research Association, joined the Mond Nickel Co. Ltd. in 1956 as leader of the cast-iron section. He took up his present position in 1958.

He is the author of many scientific papers. Recently he has been associated with the development of nickel-containing alloys of high creep resistance.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Annual Report 1958

The Annual Report of the British Iron and Steel Research Association for 1958 has recently been published. This shows an increase in the number of members and associate members. The Association's income rose to £815 019 during the year, as a result of an increased grant from the British Iron and Steel Federation and a Government block grant of £120 000.

Of the 228 research projects in progress during the year, some were of particular topical interest. The Ironmaking Division brought its direct-reduction process, now known as 'flame smelting,' to the point where quantities of molten metal free from slag could be tapped. The Steelmaking Division cooperated with a member company in the development of an improved oxygen steelmaking process. Works trials of a new system for suspending the roofs of basic open-hearth furnaces, carried out by the Chemistry Department, gave highly encouraging results in reducing the losses of cracked ends of bricks. Work on forge mechanization continued in the Mechanical Working Division, which was also collaborating with the Metallurgy Division in the extrusion of tool steels by a new process designed to disperse undesirable segregations. The Plant Engineering and Energy Division saw its translator control system for primary rolling mills taken up and applied in industry.

Work on the new block at the Battersea laboratories, which represents the first stage of the redevelopment of the site, continued during the year; the block was completed early in 1959.

Computers in the iron and steel industry

The Operational Research Department of BISRA has recently published a full report, incorporating the papers delivered and the discussion on them, of the conference organized by the Department at the Institution of Mechanical Engineers in April, 1958. This was the first conference held by the steel industry dealing with this important subject.

The contents include four main papers:

'*Experience in using a computer for payroll*,' by J. S. Pugh (Guest, Keen and Nettlefold (Midlands) Ltd., Screw Division)

'*A simulation of melting shop operations by means of a computer*,' by R. Neate and W. J. Dacey (The Steel Company of Wales Ltd.)

'*The use of a computer in a rolling mill office*,' by R. G. Massey (BISRA)

'*Training for computers*,' by D. G. Owen (The United Steel Companies Ltd.).

There is also an introduction and summing-up by Mr Stafford Beer (The United Steel Companies Ltd.), a description of the demonstrations of BISRA's *Pegasus* computer, and a glossary of digital computer terms. The 63 pages of the report include a number of charts and diagrams. One free copy will be sent, on request, to each member firm. Further copies, or copies ordered by individuals or organizations outside BISRA, are available at £1 per copy. Orders for six or more copies will be invoiced at a price of 15*s*. per copy.

NEWS OF SCIENCE AND INDUSTRY

BISF Annual Report 1958

The Annual Report of the British Iron and Steel Federation for 1958 has recently been published. The following points from the report are of particular interest.

During the year, the steel industry felt the full effect of the general slackening of economic activity in the UK and most other industrialized countries. Although the capacity of the British steel industry continued to expand, crude steel production fell by over 2 million ingot tons from the 1957 record total to 19·6 million ingot tons. There was a progressive decline in the demand for steel from the home market and exports did not reach the high level attained in 1957. Nevertheless, the British steel industry retained its share of the world market in steel. There was significant saving in imports in 1958.

The set-back in demand is regarded as a purely temporary pause in the long-term rising trend, and industry is continuing to plan its development accordingly. Capital expenditure was at a record rate of £105 million in 1958, compared with £95 million in 1957 and £75 million in 1956. The development programme is expected to be fully adequate to meet any foreseeable increase in demand.

The prospects of an early recovery in the demand for steel are now encouraging. The measures taken by the Government to stimulate the economy should help to buttress the revival of confidence and production and orders are now beginning to rise.

Mond Nickel exhibition

A private exhibition is being staged by the Mond Nickel Co. Ltd. at the Cutlers Hall, Sheffield, from 2nd–5th June, featuring the properties of nickel, nickel-containing materials, the platinum metals, and s.g. iron.

The exhibition has been designed to feature the range of company products and to illustrate the special properties which make them vital materials for many applications in modern industry. It is divided into sections dealing with mechanical and physical properties, corrosion resistance, electrodeposition, strength at high temperatures, toughness at sub-zero temperatures, and welding. These main sections are further subdivided and include demonstrations as well as specimens of materials.

Each day a number of technical films will be shown relating to various aspects of the exhibition, including films on s.g. iron, nickel alloy permanent magnets, welding, corrosion, etc.

Institute of Fuel annual luncheon

The Annual Luncheon of The Institute of Fuel was held at the Connaught Rooms, London, on 23rd April, with the President, Mr T. C. Bailey, in the chair. The principal guest was Mr C. M. Vignoles, C.B.E., President of The Institute of Petroleum.

Russian order for Stewarts and Lloyds

Stewarts and Lloyds Ltd. have recently negotiated two contracts with Russia, one for £460 000 worth of boiler and steam tubes and the other for £383 000 worth of oil-well tubing for the Russian oil industry. Much of the tonnage involved (5 500 tons for the first contract and 4 100 tons for the second) will be produced at Stewarts and Lloyds' works at Corby.

Together these two contracts constitute by far the largest order received by Stewarts and Lloyds from the USSR since before World War II.

Abbey universal mill

The universal slabbing mill installed last November at the Abbey Works of The Steel Company of Wales Ltd. is already showing its capabilities. During the week ending 19th April the mill rolled 53 733 tons of steel ingots into slabs, exceeding by 4 528 tons the highest tonnage ever rolled in one week on the old mill.

In the following week 53 152 tons were rolled; in achieving this figure the 24-hour output, starting at 6 a.m. on 20th April, reached the remarkable figure of 9 370 tons.

When new plant, at present being installed, comes into operation during the next few months, the ingot steel output of the works will gradually increase to 60 000 tons a week, all of which will be rolled through the universal mill. The outputs at present being achieved are a good indication that this higher tonnage will be obtained as soon as the extra steel is available.

Changes at MERL

The Council for Scientific and Industrial Research announces that in future the Mechanical Engineering Research Laboratory at East Kilbride, near Glasgow, will be known as the National Engineering Laboratory. This is because the Council considers it desirable to emphasize the national character of the Laboratory, which is part of the DSIR organization and is financed from public funds. It does not imply any change in the field covered by the Laboratory, which will continue to be concerned with problems of mechanical engineering.

The Council has also decided to set up a Steering Committee to look after the programme of the Laboratory. As a result of a recent review of the functions and activities of the Laboratory, the Council is convinced that, between the proper and reasonable activities of the universities and technical colleges on the one hand and research associations and private and nationalized industry on the other, there is an important place for a national establishment for research in mechanical engineering, mainly supported by public funds.

The object of the Laboratory is to establish the principles and extend the knowledge of mechanical engineering science so as to provide industry with the information it requires for the solution of its own particular problems. In order, therefore, that its work may be focused on practical objectives of real value to industry (which may involve basic or applied research or, in suitable cases, development work), the Council has decided that the planning of the Laboratory's activities and the selection of research projects can best be under the control of a small body with a measure of executive authority.

The new Steering Committee will be under the chairmanship of Vice-Admiral Sir Frank Mason, K.C.B., M.I.MECH.E., M.I.MAR.E., who is a member of the Research Council and chairman of the outgoing Mechanical Engineering Research Board. The members of the Committee will be Professor O. A. Saunders (Imperial College of Science and Technology), Mr Norman Elce (Metropolitan-Vickers Electrical Co. Ltd.), Dr D. G. Sopwith, C.B.E. (Director of the MERL), and Dr C. M. Cawley, C.B.E. (Director of Stations and Grants Divisions, DSIR).

The Committee's terms of reference are to be responsible to the Research Council for the selection of projects and for the allocation of effort to them, within the financial resources allocated to the Laboratory and such other limits as may from time to time be imposed by the Council, and to report annually to Council, submitting a research programme for the following year.

FORTHCOMING CONFERENCES

Fracture of engineering materials

The Eastern New York Chapter of the American Society for Metals will sponsor a conference on the "Fracture of Engineering

ABSTRACTS OF

Materials" to be held on 23rd–25th August on the R.P.I. campus, Troy, NY. There has been considerable activity recently in the study of fracture as a problem in metal physics. While the understanding of fracture mechanisms is currently receiving great emphasis, the translation of the present state of the knowledge for the practising engineer is no less important. It is hoped that the August conference will fill this need by reviewing the current status of the fracture problem as it relates to materials of interest to the metallurgical, materials, and mechanical engineer.

The conference fee will be $10. Those wishing to register should communicate with

Dr Ernest Nippes,
Fracture Conference Registration,
Rensselaer Polytechnic Institute,
Troy, NY,
USA.

Enquiries should be sent to

Mr Richard W. Hardt,
Fracture Conference Publicity,
General Engineering Laboratory,
General Electric Company,
1 River Road,
Schenectady, NY,
USA.

International Galvanizing Conference

Provisional arrangements are now being made for the Sixth International Conference on hot-dip galvanizing, which is to be held in Cannes, France, in May, 1961. The Conference will be organized by the European General Galvanizers Association; detailed arrangements in France will be made by its member, the Association Technique Française de Galvanisation.

Subjects for discussion at the Conference will include some or all of those mentioned below; those interested in submitting original papers for presentation at the Conference are asked to communicate with the organizers:

Works practice in general galvanizing
Bath heating and control
Galvanizing equipment
Pretreatment of steel for galvanizing
Metallurgy of galvanizing: influence of steel and bath composition
After treatments of galvanized steel
Treatment of residues
Corrosion of galvanized coatings
Quality control in galvanizing
Sheet, wire, and tube galvanizing.

A general description of the work to be covered should be sent as soon as possible. A full outline of the paper will be required by May, 1960, and provisional selection of papers will be made at that time. Papers accepted for presentation at the conference will be required in full by 1st November, 1960. Further information may be obtained from the Zinc Development Association, secretary to the EGGA, 34 Berkeley Square, London W.1.

Industrial Publications Received

Instrument Screw Co. Ltd. has produced a booklet on Rosan permanently locked inserts and studs.

"A Steel Foundry Service" is the subject of a 28-page booklet from the North British Steel Foundry Ltd.

Foundry Suppliers Ltd. of 25a Cockspur Street, London S.W.1, are agents for the specific sand-surface test apparatus type SPOF and the overhang-test apparatus described in leaflets from George Fischer Ltd. of Schaffhausen, Switzerland.

Publication No. 76 from W. C. Holmes and Co. Ltd. deals with Holmes-Western '55' gas valves.

A series of new catalogues from Crofts (Engineers) Ltd. cover fabricated steel welded-boss construction conveyor pulleys (publication 858), stationary field magnetic clutch (5833), patent magnetic clutches and brakes (5923), PowerGrip 'timing' belt drives (5927), emergency slipping devices (5922), combined spur and worm double-reduction geared motors (658), 'Multispeed' geared motor units and reduction gears (5921), worm-geared motor (5914), and 'Croft-Ring' flexible and resilient couplings (5916).

The Visco Engineering Co. Ltd. has recently issued a new brochure, no. 591, describing their 'Sprayblast' oil cooler.

Changes of Address

Delapena and Son Ltd. have moved their administrative staff to new offices in Tewkesbury Road, Cheltenham (telephone 56341). The factory remains at Zona works, on the present site (telephone 54653).

Union Carbide Ltd., Alloys Division, has opened a new office at 92 Newhall Street, Birmingham 3 (telephone Central 5011).

DIARY

1st–3rd June—American Association of Spectrographers—10th Annual Symposium on Spectroscopy—Chicago, Ill., USA.

1st–5th June—11th British Electrical Power Convention—Torquay.

17th–27th June—International Plastics Exhibition—Olympia, London.

22nd–26th June—Air Pollution Control Association — Annual Meeting — Hotel Statler, Los Angeles, Cal., USA.

24th June—Cleveland Institution of Engineers—Works visit to International Harvester Co. Ltd.—Doncaster.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 84 of the May, 1959, issue of the journal:

997. Haessner, F., and H. Weik: "Investigations on the Rolling and Re-crystallization Textures of Carbonyl-iron." *Arch. Eisenhütt.*, 1956, March, pp. 153–160. (£5 15*s.* 0*d.*)

1071. Zur, M.: "The Water Supply System of the Hoesch-Westfalenhütte A.G., Dortmund." *Stahl u. Eisen*, 1958, Aug. 21st, pp. 1191–1200. (5 15*s.* 0*d.*)

1153. Mayer, K. E., *et al.*: "Automatic Control of Basic Converter Heats." *Stahl u. Eisen*, 1958, Nov. 13th, pp. 1670–1676. (£3 15*s.* 0*d.*)

1170. Schütte, W., *et al.*: "Organization of Supplies and Production and its Place in Planning and Management." I—Economy of Materials, Planning of Work, Recording and Signalling Systems. *Stahl u. Eisen*, 1958, Aug. 8th, pp. 1045–1064. (£5)

1197. Peter, W., and W. Matz: "The Transformation Characteristics of 12–14% Cr Steels" (with discussion). *Arch. Eisenhütt.*, 1957, Dec., pp. 807–823. (£9 10*s.* 0*d.*)

1198. Brosch, H., and H. Waburek: "Production Control in Rolling Mills by means of Communicating and Signalling Systems." *Stahl u. Eisen*, 1959, Jan. 8th, pp. 23–32. (£6 10*s.* 0*d.*)

1202. Wrzesinska, E.: "The Determination of Nitrides of Aluminium, Silicon, Vanadium and Chromium in Carbon and Low Alloy Steels." *Prace Inst. Hutn.*, 1958, (3), pp. 180–183. (£4)

1204. Čabelka, I. (Chabelka): "Practical Applications of the Modern Achievements in Welding Metallurgy." *Avtom. Svarka*, 1958, June, pp. 3–12. (£5 5*s.* 0*d.*)

1212. Graue, G., *et al.*: "Extra Large Spectrographic Apparatus and Its Application in the Examination of Iron and Steel." *Arch. Eisenhütt.*, 1958, Oct., pp. 619–626. (£5 10*s.* 0*d.*)

1215. Pepperhoff, W., and H.-J. Brackseick: "Study of the Flame-temperature Radiation in an Open-hearth Furnace." *Stahl u. Eisen*, 1956, Nov. 1st, pp. 1453–1456. (£3 5*s.* 0*d.*)

1229. Varlet, J.: "Care of Rolls for Hot Rolling Thin Sheets." *Rev. Univ. Mines*, 1945, Sept. 15th, pp. 118–121. (£3)

1232. Gerlach, E.: "Roll Cracking in Sheet Mills" *Met. u. Giessereitechn.*, 1952, Jan., pp. 14–17. (£2 15*s.* 0*d.*)

1235. Sokolovskii, V. I., *et al.*: "Experimental Investigation into the Cold Reducing of Tubes." *Stal'*, 1958, Dec., pp. 1112–1117. (£4 5*s.* 0*d.*)

1251. Dascalu, S.: "Effect of Manufacturing Process upon the Nature and Amount of Nonmetallic Inclusions in Steel." *Acad. Romine Met. Studii si Cercetari de Metalurgie* (Bucharest), 1958, (1), pp. 39–52. (£5 15*s.* 0*d.*)

1253. Latour, A., and J. Schoop: "Vibration Method for Preparing Converter Linings." *Stahl u. Eisen*, 1953, Jan. 15th, pp. 81–84. (£3)

1254. Kootz, T.: "Nitrogen Absorption of Iron." *Stahl u. Eisen*, 1959, Feb. 5th, pp. 135–137. (£2 5*s.* 0*d.*)

1260. Bastien, P.: "The Cracking and Fracture of Steel Charged with Hydrogen." *Materialprüfung*, 1959, Jan., pp. 3–12. (£7)

1261. Fomichev, I. A.: "A New Method for Testing the Plastic Properties of Metals at Elevated Temperatures." *Zavods. Lab.*, 1955, July, pp. 841–844. (£3)

1269. Prolingheuer, K.-H.: "Steelworks Cranes from the Work Study Point of View." *Fördern u. Heben*, 1958, Feb., pp. 58–61. (£4)

1286. Stauffer, W., and A. Keller: "Austenitic Steel Castings for the Construction of Gas- and Steam-turbines." *Giesserei*, 1958, Apr. 24th, pp. 229–239. (£6 10*s.* 0*d.*)

1289. Pardon, L.: "Microscopical Investigation of the Crystallization of Blast Furnace Slag." *Silikaty Svazek* (Prague), 1958, vol. 2, pp. 176–181. (£1 10*s.* 0*d.*)

1294. Weber, J.: "Formation of Steam from Waste Heat and Efficiency of Dust Removal from the Converter Waste Gases of a Water-cooled Converter Stack by Cyclones." *Stahl u. Eisen*, 1959, March 5th, pp. 291–294. (£3)

1295. Oreshkin, G.: Blast Furnace Stack Cooling. Translation of a Paper entitled "We must not be influenced by Outworn Tradition." *Promyshlenno-ekonomicheskaya Gazeta*, 1958, Dec. 21st. (£1)

1297. Hoornweg, W. J.: "Modern Weighbridges." Paper presented at the Third International Harbour Congress, Antwerp, June, 1958. (£4 5*s.* 0*d.*)

1310. Claassen, A., and L. Bastings: "The Extraction of Ferric Chloride with Methyl Isobutyl Ketone and Amyl Acetate." *Z. anal. Chem.*, 1958, (6), pp. 403–409. (£2)

Catalogue cards for all translations issued by the British Iron and Steel Industry Translation Service since its inception are now available at 3*d.* each, plus postage; for new translations they are mailed every fortnight. Cards for articles listed in "Other People's Translations" (published fortnightly by B.I.S.T.S. since 27th February, 1959) can also be supplied. Please send enquiries direct to J. A. Hockley, The Madonna Press, 32a Aboyne Drive, West Wimbledon, London S.W.20 (MALden 6998).

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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*Abstracts, the reference to which is marked with an asterisk are, or are to be made available as translations.

MINERAL RESOURCES

Unknown Swiss Iron Ore Mines and an Inventory and Map of all Iron and Manganese Ore Occurrences in Switzerland. W. Epprecht. (*Schweiz. Mineralogische und Petrographische Mitteilung*, 1957, **37** (2), 217–246, reprint; *Beiträge zur Geologie der Schweiz* No. 19).

The Lias. A True Metalliferous Horizon. V. Charrin. (*Genie Civil*, 1959, **136**, Feb., 65–68). An account of the French Liassic deposits with iron and non-ferrous ore localities.

The Genesis of Magnetite Ores of the Siberian Platform. N. V. Pavlov. (*Bull. A.N., Ser. Geol.*, 1958, (9), 3–24). [In Russian]. Angara-Katanga, Angara-Vilmi and Vilmi-Kotni magnetite ores are described and their genesis discussed. These ores are intruded into shelter zones penetrated by basic intrusive igneous rocks. It is suggested that the basic magma acting on the pre-existing salt deposits gave rise to emanations and solutions of iron chlorides and fluorides which after being transported, were deposited in fissures as magnetite ore.—S. I. T.

Kuzsk Magnetic Anomalies. P. Y. Antropov. (*Priroda*, 1958, (7), 16). [In Russian]. Recent survey in the region of the well-known Kuzsk magnetic anomalies revealed the existence of a belt of highly folded Proterozoic metamorphic rocks containing bands of ferruginous quartzite buried under a cover of some 40–500 m thick later sediments. At the base of this cover and in pockets occur a very rich martite iron-ore—a product of weathering of ferruginous quartzites. The estimates for the whole region suggest as a probable figure of total reserves of a rich iron ore as 20 milliard t and a probable future annual production of 70–80 million t per annum.—S. I. T.

The Manganese-Ore Deposits in Udaipur and Banswara, Rajasthan. B. C. Roy. *Bull. Geol. Survey India, Ser.* A, (14), pp. 31).

Limestone and Dolomite Deposits in Gangpur, Sundargarh District, Orissa. S. Narayanaswamy, M. Nath, S. C. Chakravarty and A. R. Gokul. (*Bull. Geol. Survey India, Ser.* A, 1957, (12), pp. 75).

Zirconium and Hafnium in the Southeastern Atlantic States. J. B. Mertie, jun. (*U.S. Geol. Survey Bull.*, 1082-A, pp. 28).

Reserves of Manganese Ore in Brazil—Regulation of its Export. F. J. Pinto de Souza. (*Eng. Min. e Met.*, 1958, **28**, Aug., 73–75). [In Portuguese]. After a brief discussion of the present position, the author outlines the uses of Mn and gives details of the deposits and reserves, estimated at 10^6 t, in the four main regions, Mato Grosso, Amapá, Minas Gerais and Bahia. Export policy is discussed and new proposals are made which would allow the annual export of a fraction 1/n from each region. For Minas Gerais, n would be 30, but 20 is proposed for the other regions.—P. S.

ORES—MINING AND TREATMENT

Developments in Ammonium Nitrate Blasting by Iron Ore Company. H. E. Farnam jun. (*Can. Min. J.*, 1958, **12**, Dec., 58–61). The practice of the Iron Ore Co. of Canada is described.

A Survey of the Iron Ore Industry in Canada during 1957. T. H. Janes and R. B. Elver. (*Dept. Mines, Ottawa, Mineral Resources Division, Bull., MR* 27, 1958, June, pp. 116). A survey of production, ore composition and beneficiation, companies engaged and other possible locations is given.

Joda Iron Ore Mine Starts Operation. (*Iron Steel Rev.*, 1958, **2**, Oct., 407–408). The first stage of developing the Joda ore deposit in Orissa has been the construction of a 4855 ft aerial ropeway, with a capacity of 300 t per h.—A. G.

Principal Trends in the Development of Stages for the Treatment of Ores Prior to Dressing. W. K. Zachwatkin. (*Neue Hutte*, 1958, **3**, Nov., 643–650). Methods and equipment for grinding ores prior to flotation are subdivided into four stages differing in the number of grinding processes and in the use of open-circuits. The use of open-circuit rod mills as penultimate, and of ball-mills as ultimate stages is advocated.—L. J. L.

Microradiographic Study of the Action of Flotation Reagents. I. N. Plaksin, S. P. Zaitseva, G. A. Myasnikova, L. P. Starchik, V. I. Turnikova, G. N. Khazhinskaya and R. S. Shaefeyev. (*Trans. Inst. Min. Met.*, 1957–58, **67**, 1–7). Illustrated with autoradiographs. Xanthates labelled with ^{35}S were used.

Development of Tungsten Ore Dressing Practice. H. H. Kipp. (*Trans. Canad. I.M.M.*, 1957, **60**, 76–78). Practice at Canadian Exploration Ltd. Salmo, B.C. is described.

The Isolation and Separation of Niobium and Tantalum Pentoxides from Mineral Concentrates by Liquid-Liquid Extraction. G. H. Faye and W. R. Inman. (*Trans. Canad. I.M.M.*, 1957, **60**, 343–347). The treatment of pyrochlore ores and the extraction and separation of Nb and Ta from HF–HNO_3 solution with methyl *iso*butyl ketone (2-methylpentan-4-one) is described on the laboratory scale. 99·5% purity and 95% recovery were attained.

Wire Ropes for Mines. W. E. Brown. (*Trans. Canad. I.M.M.*, 1957, **60**, 318–325). Properties of the ropes and the wire and core materials used and selection for the various purposes are discussed.

The Recovery of Molybdenum from Acid Solution Using Potassium Ferrocyanide. D. Robbins. (*J. Appl. Chem.*, 1958, **8**, Dec., 777–781).

Study on the Utilisation of Laterite. On the Recovery of Nickel in Laterite. II. M. Tanaka. (*Tetsu to Hagane*, 1958, **44**, Mar., 281–282).—K. E. J.

Fundamental Studies on the Magnetic Roasting of Iron Ores. II. A. Kondo. (*Tetsu to Hagane*, 1958, **44**, Mar., 282–284). The effects of varying hydrogen flow rate at 500° C on the metallic iron content and magnetite content are traced; higher flow rates give less magnetite.—K. E. J.

Agglomeration of Iron Sand with a Rotary Kiln. T. Yamamoto. (*Tetsu to Hagane*, 1958, **44**, Mar., 284–286).—K. E. J.

Flash Roasting of NF Sulphide Ores to Sulphate. G. Ya. Leizerovich, I. S. Lonskii and V. Z. Charnyi. (*Tsvetnye Metally*, 1957, **13**, (9), 19–25; *Neue Hutte*, 1958, **3**, (9), 567–568). A pilot plant is described treating a Cu–Pb–Zn ore with 24·9%Fe and temperature and other conditions are investigated. Full scale operation is regarded as possible.

The Metallurgical Evaluation of Iron Ores and Other Raw Materials. A. N. Pochvisnew. (*Metallurgie u. Giesserei-Technik*, 1955, Mar., 82–85). The concept of heat equivalent of A. N. Ramm is developed taking into account coke rate and costs. An example for the blast furnace is worked out and numerical values are given.

Sintering Plant Now in Operation at the Ashland Works. Armco Steel Corp. (*Blast Furn. Steel Plant*, 1958, **46**, Dec., 1297–1300). The 2400-t per day sintering plant now in operation at the Ashland, Kentucky works for the agglomeration of iron ore fines and other raw materials is described, several photographs of the plant being included.

Sintering: 5000 Tons a Day! (*Met. Prog.*, 1958, **74**, Sept., 74–77). The new sintering plant of the Ohio Works of U.S. Steel Corp. is described and illustrated. The plant is virtually automatic, it produces a strong porous cake and the fines formerly lost are now used. By charging sinter in the blast furnace the capacity of the furnace is raised by 25%.—T. G.

Study on Sintering Factors, Particularly the Air-Flow through the Sinter Bed. H. Toyozawa. (*Tetsu to Hagane*, 1958, **44**, Mar., 289–291). [In Japanese]. Measurements were made of air flows and temp. in the suction pipeline and windboxes, and of air flows in the hood. From these, results are given for leakages on the fan and temperatures and sintering speeds at varying depths in the bed.—K. E. J.

Sintering of Small Green Pellets (Semi-Pellets) Mixture. M. Serizawa. (*Tetsu to Hagane*, 1958, **44**, Mar., 286–288). "Semi-pellets" of pyrites cinder and Goa fines of size 2–5 mm are stronger than those of sizes 5–10 and 10–15 mm, and strength is improved by lime additions up to 5%. With 40% of "semi-pellets" sintering time is at a min. and yield at a max.—K. E. J.

Effect of Moisture on the Sintering of Iron Ore Mixture. A. Senda. (*Tetsu to Hagane*, 1958, **44**, Mar., 296–299). For various ores and sinter mixes (compositions and size analyses given), the production degree (in $t/m^2/min$) reaches a maximum with variation in moisture content; the corresponding moisture content varies between 6% and 10% according to the mix.—K. E. J.

Study on the Sintering of Mixed Ores. On Magnetite Mixed with Limonite. T. Sakakibara. (*Tetsu to Hagane*, 1958, **44**, Mar., 291–293).—K. E. J.

Influence of Various Basic Additions on the Physical Properties of a Siliceous Ore Sinter. J. A. Boned Sopena. (*Inst. Hierro Acero*, 1958, **11**, July-Sept., 155–167). [In Spanish]. Siliceous ore of the Paz del Rio (48·80%Fe, 9·55%SiO_2, 7·65%Al_2O_3), ground to 5 mm, was used for the experiments. Additions of material such as lime, dolomite and magnesite were made to give charge basicity indices ranging from 0·3 to 1·2. ($i = (CaO + MgO)/(SiO_2 + Al_2O_3)$). The charges made with dolomite ($i = 0·4$), calcined dolomite ($i = 0·6$ and 1·1) and lime ($i = 0·3$ and 0·5) gave the coarsest sinters, though sinters of the ore alone were somewhat coarser; the coarseness is independent of the % coke addition and seems to depend on the nature and amount of the basic materials added. Sinters of good size were obtained with 21·4% calcined dolomite ($i = 1·04$). It is shown that there is a close correlation between the degree of oxidation and the fines (0–2·5mm) in the sinter as found by screening so the degree of oxidation can be used as a criterion of physical quality; there is also a statistical correlation between the degree of oxidation and the ratio standard deviation/mean particle size found by the Micum drum test.—F. S.

Powdering of "Harada's Briquettes." Sinter and Pellets during CO Roasting. T. Oshiumi. (*Tetsu to Hagane*, 1958, **44**, Mar., 295–296). Results are given for powder formation from sinter, briquettes and pellets at various temp. in CO gas, and at 500° C in atmospheres of ($CO + CO_2$) and (CO, $CO_2 + N_2$).—K. E. J.

Suitability of Anthracite as a Sintering Fuel. K. Miyakawa. (*Tetsu to Hagane*, 1958, **44**, Mar., 293–295). Various properties and sintering characteristics of anthracite are compared with those of coke breeze. In general, sinter strengths and yields are lower with anthracite.—K. E. J.

Sintering of Ore Fines and Muds. L. Visnyovszky and T. Holló. (*Koh. Lapok*, 1958, **13**, Oct.-Nov., 477–481). In this first part of the paper the authors critically review various sintering methods applied in Hungary and elsewhere. They also describe Hungarian experiments on pelletizing ore fines for preparing them for sintering.—P. K.

Chlorination of Fines During Sintering. H. Neuhaus and H. Schenck. (**Stahl Eisen*, 1958, **78**, Nov. 13, 1662–1670). The authors discuss the effects of impurities in concentrates, pyrites, dusts and sludges on the quality of the iron produced from them; zinc being the element of the highest concentration, followed by lead, copper, etc. The attempt was made to remove these elements via the gas phase. The fines were sintered whilst ammonium chloride, magnesium chloride or calcium chloride was added as a slurry, the water aiding the vaporization of the heavy-metal chlorides formed. It was found that only calcium chloride showed a sufficient chlorinating effect and at the same time permitted a high output of sinter and a high strength of the briquettes. A 4% addition of powdered limestone markedly increased the removal of zinc, a rate of 76% being obtained.—T. G.

The Corrosion of Coke Oven Linings in Conditions of Ferrocoke Production. M. Starczewski. (*Prace Inst. Hutn.*, 1958, (5), 255–259). Fireclay and silica brick linings were examined in full-scale tests. The pusher charger produced much erosion and blackening due to carbon deposition from CO catalysed by iron compounds occurred. The bricks in laboratory tests were not resistant to CO at 500° C.

FUEL—PREPARATION, PROPERTIES, AND USES

Geology and Coal Resources of the Centralia-Chehalis District, Washington. P. D. Snavely, jun., R. D. Brown, jun., A. E. Roberts and W. W. Rau. (*U.S. Geol. Survey Bull.*, 1053, 1958, pp. 159).

Geology and Coal Resources of the Tiptop Quadrangle, Kentucky. S. W. Welch. (*U.S. Geol. Survey Bull.* 1042-P, 1958, 585–612).

A Revision of the Geology and Coal Resources of the Jharia Coalfield. D. R. S. Mehta and B. R. Narayana Murthy. (*Mem. Geol. Survey India*, 1957, **84**, pp. 142).

Coal Preparation with Particular Reference to Carbonisation Coals. D. A. Hall and H. Macpherson. (*Gas World*, 1958, **148**, Dec. 6, 103–113).

Relationship of the Properties of Coals and Coal Blends with the Quality of Coke Produced. H. McKellar, W. Burns and V. Giedroyc. (*J. Inst. Fuel*, 1958, **31**, Dec., 528–534).

The Rheological Properties of Water Suspensions of Finely Subdivided Magnetite, Galena and Ferrosilicon. G. V. Govier, C. A. Shook and E. O. Lilge. (*Trans. Canad. I.M.M.*, 1957, **60**, 147–154). Settling rates and viscosities are determined.

Careful Transshipment of Coke and Coal in Emden Harbour. K. Schmoll. (*Demag Nachr.*, 1958, (154), 18–22). Details are given of the equipment and techniques used for the transshipment of coke and coal at Emden to avoid damage to the material.

Coking Conditions and the Mechanical Preparation of Coals. R. Loison. (*Inst. Nac. Carbon Bol. Inf.*, 1958, **7**, May-June, 95–121). Factors in plant operation and coke quality resulting from preparation such as ash, moisture, particle size, S and P are discussed. Exact knowledge might be of value in steelworks.

Chemical Structure and Properties of Coal XXI—The Kinetics of Coal Carbonization. D. Fitzgerald and D. W. van Krevelen. (*Fuel*, 1959, **38**, Jan., 17–37). Previous work has been based on loss of weight and hence mainly on tar formation. This study is based on the gases evolved.

The Mechanism of Coking. M. Szücs and L. Gärtner. (*Koh. Lapok*, 1958, **13**, Oct.-Nov., 491–497). A review. (78 refs.).

Study on the Manufacturing Conditions of the Coke Used for the 1500-ton Blast Furnace. I. S. Ida. (*Tetsu to Hagane*, 1958, **44**, Mar., 303–306). Blending data, coking conditions and coke properties are compared for coke produced by United Steel Corp., Philadelphia Coke Co., Southern Colliery (Australia) and Yawata Iron and Steel Works.—K. E. J.

The Role of Carbon Dioxide Reduction in the Combustion of Coke. S. F. Chukhanov. (**Brennstoff-Chemie*, 1957, **38**, Oct. 16, 289–297). Various regions of reaction are distinguished and the part played by the CO_2–C reactions in combustion is discussed.

On the Heating Value of Coke, On the Calculation of a Formula of Heating Value Based on Technical Analysis of Coke. S. Nishida. (*Tetsu to Hagane*, 1958, **44**, Mar., 300–302). The compositions and heating values of cokes heated at various temp. between 650° and 1550° C are given; and experimental results give the heating values of the gas and the residue.—K. E. J.

AIR POLLUTION AND SMOKE

The Estimation of the Darkness of Smoke by Visual Methods. L. E. Reed. (*J. Inst. Fuel*, 1959, **32**, Jan., 3–9).

Water Plots Air Flow. (*Steel*, 1958, **143**, Nov. 10, 124). This short article describes how a water-flow model is used to study the air flow characteristics of designs for electric precipitators.—D. L. C. P.

Phase-Contrast Microscopy in Dust Technology. K. G. Schmidt. (**Staub*, 1955, **4**, 436–464). A method of mineral dust identification by examination of immersed samples is described.

TEMPERATURE MEASUREMENT AND CONTROL

Improvement in Measurements by the Immersion Pyrometer. K. Nakamachi. (*Tetsu to Hagane*, 1958, **44**, Mar., 239–241).

Accuracy of Optical Pyrometry in the Range 800° C to 4000° C. D. R. Lovejoy. (*Can. J. Phys.*, 1958, **36**, Oct., 1397–1408). High precision work suggesting a revision of the International Temperature Scale is reported.

REFRACTORY MATERIALS

Research on Refractories at Imperial College. L. R. Barrett. (*Refract. J.*, 1958, **34**, Nov., 494–498). Title of theses since 1948 are added.

Properties of the Refractory Bricks Currently Used. (*Stahl Eisen*, 1958, **78**, Nov. 27, 1754–1755). A list compiled by the Verein Deutscher Eisenhüttenleute of the physical properties, chemical analysis and fields of application of refractory bricks under the headings: Properties of Bricks for Pig Iron and Steel Ladles; Properties of Fire-Clay Bricks Class A (up to 45% Al_2O_3); and Properties of Silica Bricks for Steel Works.

The Behaviour of Basic Bricks in Reducing Atmospheres and Their Behaviour as Regards Carbon Monoxide and Methane Disintegration. G. Reinhardt. (**Tonindustrie Zeitung*, 1958, (3–4), 38–41). The effect of reducing gases on experimental magnesite refractories is shown to depend upon attack on the iron content and carbon deposition. Methane attacks the brick more rapidly than CO, but the mechanism is very much the same.

Effect of Composition of Kiln Atmosphere in the Firing of Refractory Oxides. F. Sandford and E. Eriesson. (*J. Amer. Ceram. Soc.*, 1958, **41**, Dec., 527–531). Al_2O_3 is shown to lose O_2 at 1400–1500° C in water vapour but the weight does not change in air or N_2. Kiln gases dissolve in mullite at 800–1200° C, solubility increasing with temperature. The latter observation is connected with lattice defects.

Distinguishing between Mullite and Sillimanite by Infra-Red Spectrometry. P. Tarte. (*Silicates Ind.*, 1959, **24**, Jan., 7–13).

Stabilisation of Dicalcium Silicate in Magnesite-Dolomite Products. F. Nadachowski. (*Prace Inst. Hutn.*, 1958, (5), 237–242). Tests with a phosphate stabilizer were made. Disintegration of 3CaO, SiO_2 and 2CaO, SiO_2 do not occur with correct stabilization and the phosphate is decomposed only by solid C. About 1·5%P_2O_5 is recommended.

The Effects of the Addition of Barium Oxide on the Phase Composition of Basic Refractories. M. Grylicki and F. Nada-

chowski. (*Prace Inst. Hutn.*, 1958, (5), 243–254). Mineralogical examination of mixtures of pure components was made at equilibrium, and phases and their refractoriness and optical properties were determined in the system BaO–MgO–CaO–SiO_2 and also with Al_2O_3 and Fe_2O_3.

Studies on the Mechanism of Corrosion against the Refractories from a Zebra Roof in Basic Open-Hearth Furnaces. T. Ao. (*Tetsu to Hagane*, 1958, **44**, Mar., 235–237).

Phase Equilibria in the System CaO–Iron Oxide in Air and at 1 Atm. O_2 Pressure. B. Phillips and A. Muan. (*J. Am. Ceram. Soc.*, 1958, **41**, Nov. 1, 445–454). The quenching method was applied to the iron-rich portion of the system.

Furnaces of Refractory Concrete. L. Longchambon. (*Usine Nouv.*, 1959, **15**, Jan. 15, 31, 33, 35, 37). The properties of refractory cements and their resistance to aggressive media are discussed and the construction of furnaces of various kinds and parts of furnaces is described. The temperatures at which the various materials can be used are indicated.

Practical Test of Erosion-Resisting Soft Sleeve Bricks. H. Ishida. (*Tetsu to Hagane*, 1958, **44**, Mar., 335–337). Physical and chemical properties before and after service in the ladle are tabulated, and results of steelmaking operations are given.—K. E. J.

An Experimental Comparison of the Methods of Testing by Thermal Shock Undertaken by the Commission Technique et Scientifique P.R.E. R. Fourneau. (*Silicates Ind.*, 1959, **24**, Jan. 14–20).

IRON AND STEEL, GENERAL

Review of Modern Developments in the Steel Industry. F. De Carli. (*Fonderia*, 1958, **7**, Dec., 523–532). The author reviews the principal developments which have affected the production of iron and steel in recent years. Ore beneficiation, pelletizing, sintering, the all-basic O. H. furnace, the greater productivity through the use of larger units, modern oxygen steelmaking methods, L-D steel and other recent developments are discussed briefly.—M. D. J. B.

Belgo Mineira Has Started to Carry Out Its Second Phase of Expansion. (*Eng. Min. e Met.*, 1958, **28**, Aug., 76). [In Portuguese]. It is planned to produce 500 000 t of steel annually. Blast furnace capacity is being increased by modification of existing plant. The new wire mill should become partly operational next August in the galvanizing, annealing and barbed-wire making sections; it will be one of the largest plants in the world, with a production reaching 200 000 t annually, and will make Brazil independent in wire and wire products.—P. S.

The Mandeville Works of the Société Métallurgique de Normandie. (*Mét. Constr. Méc.*, 1958, **90**, Dec., 923–929). An illustrated description of the plant and its operation.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Report on "E" Blast Furnace, Tenth Lining. J. W. Carlson and A. E. Frey. (*Blast Furn. Steel Plant*, 1958, **46**, Dec., 1279–1286). A report on the dismantling and inspection of the lining of the first blast furnace to be taken out of production that had machined and keyed carbon blocks. A record production was achieved, the use of a carbon hearth and a carbonaceous taphole mix was satisfactory, and there was evidence that a definite freeze zone was established.

Tisco's New Blast Furnace at Burnpur. (*Iron Steel Rev.*, 1958, **2**, Oct., 405–406). The furnace has a 25 ft hearth and will produce 1 200 t of pig iron daily, bringing the total output of TISCO to 1·3 million t a year.

Tisco's New Blast Furnace at Jamshedpur. (*Iron Steel Rev.*, 1958, **2**, Oct., 403–404). The furnace, one of the largest in the world, is equipped for high top pressure operation and will operate on a sinter burden.—A. G.

On the Repairing of Nakamachi No. 2 Blast Furnace and its Blowing in. A. Tayama. (*Tetsu to Hagane*, 1958, **44**, Mar., 276–277).

Blast Furnace Operation with Western Raw Materials. J. D. Saussaman. (*Iron Steel Eng.*, 1958, **35**, Nov., 77–81). Experience of the Kaiser Steel Corporation in smelting ores of variable composition and high sulphur, and using inferior fuels and fluxes is outlined.

The Economy of Blast Furnace Operation. F. Gèmes. (*Koh. Lapok*, 1958, **13**, Oct.–Nov., 469–476). The author discusses the effect of specific coke consumption, production of pig iron and flux dust, and utilization of top gas on the economy of blast furnace operation.

The Assessment of Blast Furnace Coke. W. Zimmer. (*Neue Hütte*, (958, **3**, Nov., 666–673). Conventional methods of testing blast-furnace coke are discussed; rattler tests are found wanting; suggestions are made for a determination of the metallurgical behaviour of undersize in blast furnaces; the establishment of a "uniformity coefficient" is advocated.—L. J. L.

The Analysis of Methods of Drying and Blowing in Blast Furnaces in Polish Metallurgical Plants. S. Zieliński and A. Maslanka. (*Hutnik*, 1958, **25**, (7–8), 250–257). [In Polish]. The need to obtain the full productive capacity of a blast furnace in the shortest possible time leads to shortening of the period for drying of a new refractory lining and of the initial stage of blowing. The average useful time of operation of a refractory lining in Poland is only 2·5–3 years, i.e. about 50% of that in foreign countries. To find proper methods, questionnaires have been sent to all plants with blast furnaces. Data concerning 19 furnaces, representing 76% of the total number, were received. These data were analysed and compared with analogous data in the U.S.A. Polish and American methods of blowing are similar, those of drying differ. Some improvements are suggested. Further studies are needed.—S. S.

Smelting Low Manganese and Phosphorus Pig Iron. B. N. Zherebin, V. P. Dembovetskii, V. M. Minkin and I. D. Nikulinskii. (*Stal'*, 1958, (7), 578–585). Experiments carried out under production conditions at Kuznetsk to produce low manganese pig iron for steelmaking showed that optimum results were obtained when all Mn additions were excluded from the burden. Blast furnace productivity was raised by 5·4%, coke consumption per t of iron was reduced by 5·6% and iron costs were lowered by 5*s.* per t. Good quality rail and alloy steels have been produced from the iron.—R. S.

Processing of Titanium-Bearing Iron Ore in the Blast Furnace. E. Wendel. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1603–1605). A comprehensive review of published information on the processing of Ti-bearing ores in the blast furnace. It is concluded that under conventional conditions the TiO_2 content of the slag may amount to 1·5–2% without impairing furnace operation. When producing Si-bearing iron, the TiO_2 content may increase to 4–5%. In the last century, ores containing up to 40%TiO_2 were processed in cold-blast operation, the slag also contained about 40%TiO_2. (21 references.)—T. G.

Calculation of Coke Consumption for Blast Furnace Smelting by means of the Overall Heat Balance. B. N. Yur'ev. (*Stal'*, 1958 *Supplement* "*Blast Furnace Production*," *Metallurgizdat*, 1958, 96–124). The article gives a critical summary of existing methods, and reviews the more important, such as the complex method of A. N. Ramm and the method of A. P. Lyuban. It then proposes a new method by which it is possible to bring the calculations down to a simple and graphical form familiar in metallurgical computations. The results obtained show a desirable accuracy and avoid complications and loss of time.

Analytical Method for Calculating Coke Consumption in Blast Furnaces. G. V. Ksendzyk. (*Stal'*, 1958 *supplement* "*Blast Furnace Production*," *Metallurgizdat*, 1958, 125–137). The theoretical basis of an analytical method of computation devized for zonal heat diagrams is explained. The basic initial characteristics; chemical content of the pig iron produced, of the slag and coke, the quantity of slag, the temperature of the blast, the stages of direct reduction of iron, the content of CH_4 in flue gases and the carbon in dust are then used in the formulae devized.

Effect of Zinc on the Refractory Linings of Blast-Furnaces. V. I. Kholzakov and L. M. Tsylev. (*Izvest. Akad. Nauk Otdel. Tekn.*, 1958, (3), 89–95). One of the causes of expansion and erosion of furnace linings when melting zinc-containing ores is the formation of an iron–zinc alloy containing between 4–20% iron. This can be formed by contact of metallic zinc with the iron-containing slag-hardened crust on the sides of the blast furnace between 650 and 800°. This alloy acts as catalyst in the dissociation of carbon oxides and the liberated carbon black contributes to the destruction of the linings.—L. H.

Investigating the Wear of Brickwork in Blast Furnaces by Means of Radioactive Isotopes. Holzhey. (*Technik*, 1958, **13**, Aug., 542–544). Results are reported of work over the past twelve months at the Stalin Steel Works in Stalingrad with radioactive isotopes to determine at which points in the lower sections of a blast furnace wear is greatest and what is the rate of wear. ^{60}Co was used as the source of radiation: the cobalt elements were enclosed in Cr–Ni steel containers which in turn were enclosed in carbon sheaths.—L. J. L.

Improving the Life of Blast Furnace Refractories. N. F. Kozinskii. (*Stal'*, 1958, (10), 883). The main cause of failure of stack linings is carbon black. The porosity of the brick must not exceed 6%. The use of chamotte brick has led to some improvement, and it has been shown that carbon black and not Zn is responsible for failure. A reduction of iron content to 1·2% and heating to 1450° improved the resistance to carbon. Specimens did not fail in CO for 200 h in the dangerous range 450–500° C.—R. S.

Recent Innovations in Blast Furnace Maintenance and Rebuilding. L. Torok. (*Iron Steel Eng.*, 1958, **35**, Sept., 173–175). Three measures used to facilitate the dismantling of, or repairs to blast-furnace linings at the Bethlehem plant of the Bethlehem Steel Co. are described.

The Hearth-Bottom Mantle and the Hearth in Blast Furnaces. L. A. Sorokin. (*Stal'*, 1958 *supplement* "*Blast Furnace Production*," *Metallurgizdat*, 1958, 75–83). Excessive strain must be avoided by reducing the pressure of linings and coolers on the mantle by eliminating bi-axial stress systems and by reducing local and marginal stresses on the fissures and cracks in the mantle. Ways and means are suggested to this end.—L. H.

The Problem of the Burning Through of Blast Furnace Hearths. V. Friedrich. (*Hutn. Listy*, 1958, **13**, (9), 800–802). An investigation is made of various aspects of the burning through of chamotte and carbon lined hearths, the way in which this occurs and its causes. In chamotte hearths this occurs primarily in the region of the tap-hole, and is associated with technical furnace maintenance, while in the latter instance it arises mainly from defects in the lining of the hearth or when furnaces are first put into operation, when new or refitted.—M. T.

The Desulphurization of Iron Melts with Solid Lime and Dolomite. W. A. Fischer and H. Spitzer. (*Arch. Eisenh.*, 1958, **29**, Sept., 535–542). Equilibrium between iron melts with C contents from 0·3% to saturation and solid lime or dolomite was investigated in the temperature range 1200–1700° C. An equilibrium constant K = 46·5 was derived for the reaction

$$<CaO> + [C] + [S] = <CaS> + \{CO\},$$

no temperature relationship being detected. The investigations showed CaS to be soluble in the CaO; the desulphurizing action of solid CaO is increased by small fluorspar additions, but greatly diminished by dissolved ferrous oxides.

Gas Turbines for Blast Furnace Blowing. G. H. Krapf and J. O. Stephens. (*Iron Steel Eng.*, 1958, **35**, Sept., 142–149). The design and performance of a gas-turbine blower using blast furnace gas, installed by United States Steel Corporation are described.

Novelties in the Construction of Inclined Hoists for Blast Furnaces. (*Demag News*, 1957, (147), 23–28). Descriptions of a bucket installation at Duisberg and a skip installation at Donawitz with winch driving motors fed through grid-controlled mercury-vapour rectifiers are given.

Equipment of Blast Furnace Plants. N. I. Vlasov. (*Stal'*, 1958 *supplement* "*Blast Furnace Production*," *Metallurgizdat*, 1958, 84–95). The author deals in some detail with general considerations such as the organization for tending, maintaining and repairing the plant, for the production proper, for spares, repairs to vital centres, construction etc. and gives a comparative study of these conditions at the Magnitogorsk, Zaparozhstal' and Azovstal' plants.—L. H.

Modern Attacks on Iron Ores. C. F. Hoffman. (*Met. Prog.*, 1958, **74,** Sept., 67–70). The author predicts that for any further extension of the iron smelting industry direct reduction methods will be used—a number of methods are briefly described—and the conventional blast furnace practice will be improved to produce 67% more iron from the same unit than in 1940.—T. G.

The Valuation of Surplus Top Gas. G. Bremer. (*Stahl Eisen*, 1958, **78,** Dec. 25, 1867–1871). Economics. The principles of pricing of surplus top gas are discussed.—T. G.

The Possibilities of the Utilisation of Carbon Monoxide-Containing Gases for the Synthesis of Hydrocarbons. H. Kölbel. (**Chemie-Ingenieur-Technik*, 1957, **29,** 505). (Summary only). The economics of gas sources and the possible synthetic processes are briefly indicated. Tests on blast-furnace gas are referred to.

Utilisation of the Sludge from Gas Scrubbers. B. Weilandt and F. Kruse. (**Stahl Eisen*, 1958, **78,** Nov. 13, 1657–1662). Wet sludges from the gas cleaning plants of blast furnaces cannot be charged back into the furnace on account of their high water content, very fine particle size and high zinc content. The quantities of sludge discharged from the scrubbers of one plant vary from 8000 to 10,000 t per month according of the size of the plant, i.e. the quantities are so large that their utilization is imperative. Sinter trials for briquetting and dezincification were successful, although the moisture content must be controlled between very narrow limits.—T. G.

PROPERTIES, TREATMENT, AND USE OF SLAGS

Blast Furnace Slag. F. Keil. (**Translation from book published by Verlag Stahleisen, Düsseldorf*, pp. 160–163). The disintegration of slag is related to composition in these pages.

Basicity of Blast-Furnace Slags. K. Mori. (*Tetsu to Hagane*, 1958, **44,** Mar., 308–309).

The Use of Blast-Furnace Slags in Agriculture. I. Palfalvi. (*Koh. Lapok*, 1958, **13,** August, 367–374). In this second part of the paper the author considers the effect of blast-furnace slags on the following properties of various soils: (1) pH, (2) lime content, (3) exchangeable basic ions, (4) N_2 content, (5) CO_2 formation. On the basis of the experimental results, the contents of CaO + MgO, CaO, and CaS are specified, and also the grain size. The slag must be kept dry. Some economic considerations are also given.—P. K.

Studies on Ferro-manganese Slags. III. On the Apparent Equilibrium of the Si-Reducing Reaction in Producing H-C-Mn. II. I. Tanabe, H. Saito, T. Nishida and K. Oku. (*Nippon Kinzoku*, 1956, **20,** Nov., 593–597). Using synthetic slags, a study was made of the "apparent equilibrium constant." $K^a_{Mn-Si} = (\Sigma Mn)\sqrt{[Si]/[Mn]}$, and in the range 1410–1510° C the following relationship was found: $K^a_{Mn-Si} = -1{\cdot}318\,(CaO + 1{\cdot}39\,MgO)/SiO_2 - 7381{\cdot}9/T + 4{\cdot}879$. These results were compared with practical data, and the effect of sulphur on the "apparent equilibrium" was investigated.—K. E. J.

DIRECT PROCESSES

A New Direct Reduction Method. M. J. Udy and M. C. Udy. (*Met. Prog.*, 1958, **74,** Dec., 92–94). The authors describe the Strategic–Udy process of direct reduction. The plant consists of a direct-fired rotary kiln that partially reduces the ore before it is charged into an electric-arc smelting furnace. The economics of the process are discussed and it is pointed out that the salient feature of the process is that no ore preparation is required.—T. G.

Direct Reduction by Electric Furnace. (*Blast Furn. Steel Plant*, 1958, **46,** Dec., 1303–1304; from *J. Four. Elect.*). A brief outline is given of the electric furnace plant for iron ore reduction installed by Demag at Acesta, Brazil.

PRODUCTION OF STEEL

A Short Account of the Russian Federal Conference on Steel Making, Held in Sverdlowsk in 1957. E. Weigl. (*Koh. Lapok*, 1958, **13,** Oct.-Nov., 498–501). The author reports only the topics of interest to the Hungarian Steel industry, as follows: (1) Heating of hot top with the electric arc, or oxy-acetylene; (2) Up- and down-hill ingot teeming; (3) Low-alloy constructional steels, such as 14XGC with 0·15–0·16%C, 0·4–0·7% Si, 1·0–1·3%Mn, 0·5–0·8%Cr, and more than 4 mkg/cm² impact resistance at − 60° C, and 25XGC with 0·20–0·29%C, 0·6–0·9%Si, 1·2–1·6%Mn. 14XGC steel is treated with Al and Fe-Ti in the ladle; (4) New refractories, such as checker bricks containing 50%Al_2O_3; (5) Consumption of ingot moulds. The chemical composition limits of the best ingot moulds are:

Ingot weight	C%	Si%	Mn% max.
3t max. ..	3·4–4·0	1·6–2·0	1·0
3–10t ..	3·5–4·2	1·4–1·8	1·0

Ingot weight	P% max.	S% max.	Cr% min.
3t max.	0·20	0·10	—
3–10t	0·20	0·10	0·10

(6) Use of oxygen in electric arc furnaces. At the present time, oxygen is used for the refining of every charge which does not contain V.—P. K.

The Fores Steelworks. G. Sorin. (*Rév. Gén. Méc.*, 1958, **42,** Oct., 477–479). A pictorial record of the works and its products.

Weirton Steel Company. (*Iron Steel Eng.*, 1958, **35,** Nov., W1–W84). A pictorial record and description of the products of and equipment of the Weirton Steel Company.

Jones & Laughlin Producing Stainless Steels and Strip at Ohio Plant. M. K. Schnurr. (*Blast Furn. Steel Plant*, 1958, **46,** Dec., 1295–1296). The equipment and operation of the new Louisville plant of Jones & Laughlin are described.

The Steel Plan of Otanmaki Oy as Part of the Industrialisation of Finland and in Particular of the Northern Part of the Country. V. Leskinen. (**Lecture to National Economics Association of Finland*, Mar. 20, 1958). Labour and economic problems are discussed as well as the proposed equipment and output.

Flame Radiation in a Furnace. II. Soot Concentration and Flame Radiation Blackness. H. Maesawa. (*Tetsu to Hagane*, 1958, **44,** Mar., 390–392). For two oil fuels (compositions given) the effects of varying atomizing pressure and excess air on the emissivity, mean flame temp. and soot concentration are described.—K. E. J.

Oxygen Plants—Operation and Maintenance in Steel Industry. (*Ind. Heat.*, 1958, **25,** Aug., 1563–1564, 1566, 1568, 1570). Abstracts of the A.I.S.E. Annual Convention in Pittsburgh 1957 are given.

New Plants Built in the Converter and Open-Hearth Steel Works of an Integrated Iron and Steel Works. W. Heischkeil, K. Becker, G. Leiber and R. von Moos. (**Stahl Eisen*, 1959, **79,** Jan. 8, 8–22). The rebuilding of the August-Thyssen-Hütte at Duisburg-Hamborn is described and the reasons for putting more emphasis on O.H. steel plants than on converter plants are discussed. The new O.H. steel plant is described in detail and comparisons are made between this and other plants erected elsewhere in Germany and abroad. The choice of large O.H. units with shallow hearths had proved best with respect to production costs and to quality of the steel.

Engineering Aspects of Modern Basic Bessemer Plants. H. Hofmeister and C. Herrmann. (*Demag News*, 1957, (149), 1–8). Layout and constructional details are shown.

Some Aspects of Tropenas Converter Steel. G. H. Ford. (*Eng. Foundryman*, 1958, **24,** Aug., 72–73). Alexander Medal Paper. The author describes briefly the principle and operation of the side-blown converter.—T. G.

The Development and Present State of the LD Process. O. Cuscoleca and K. Rösner. (*JISI*, 1959, **192,** June, 147–153). [This issue].

Comments on the OLP Process. B. Trentini, P. Vayssière, and M. Allard. (*JISI*, 1959, **192,** June, 143–147). [This issue].

Experience of Multiple-Strand Continuous Casting. R. Baake and H. Rosahl. (*Neue Hütte*, 1958, **3,** Dec., 740–746). The characteristics and operational details of the large-scale 3-strand continuous casting plant at Freital are described; an important feature is the control system, which is described in detail.

Underground Continuous Casting in Russia. N. Zasorin and Y. Stepanov. (**Znaniye-Sila*, 1956, Apr. 12). A brief description is given.

Study on the Solidification Process of Ingots. I. Sampling Method for Molten Steel near the Solidus in the Large Ingot during the Solidification Process. S. Maekawa and Y. Nakagawa. (*Tetsu to Hagane*, 1958, **44,** Apr., 467–470). The sampler is described; it depends on the use of a small copper plate which melts and allows ingress of molten steel at the required location. It was used to collect samples at 1480–1510° C, at 1–2·5 m below the surface of 9–20-t ingots. **II. Chemical Variations of Molten Steel near the Solid Phase of a Large Ingot during the Solidification Process.** (May, 546–552). During solidification, C, Si, Mn, P, S, H and N concentrated in the liquid phase. The total quantity of oxygen near the solid-liquid boundary tended to decrease, except near the sink-head; Al_2O_3 and MnO followed the same tendency, and SiO_2 the reverse.—K. E. J.

Some Cossiderations on Rimming Action Control. K. Yamada. (*Tetsu to Hagane*, 1958, **44,** Mar., 262–264). The effects of O_2 content, the amount of Al added and teeming level are discussed.—K. E. J.

Study on Cracks in the Killed Steel Ingot. I. Longitudinal Cracks. II. Consideration of Transverse Cracks. N. Sugiyama. (*Tetsu to Hagane*, 1958, **44,** Mar., 316–318; 318–319).

Segregation at the Top of a Rimmed Steel Ingot. Influences of Track Time and Ingot Size. K. Kugai. (*Tetsu to Hagane*, 1958, **44,** Mar., 266–268). Results for segregation of S, C, P and As are given for ingots of several types, of weight between 1·8 and 5 t.—K. E. J.

Study on the Segregation in the Upper Parts of Rimmed Ingots. T. Ooka. (*Tetsu to Hagane*, 1958, **44,** Mar., 268–270). Relationships are traced between the depth of laminar scum in the slab and the Al addition in the ladle, the depth of mechanical pipe and the Al addition, and the depth of ingot scum and the rimming time after capping.—K. E. J.

Hot-Workability of the Segregation Zones in the Killed Steel Ingot. J. Kubodera. (*Tetsu to Hagane*, 1958, **44,** Mar., 272–274). For various top- and bottom-poured ingots, relationships between the test temp. and the defect index and between ingot height and defect index are shown.—K. E. J.

On Abnormal Segregation in Steel Ingots. Y. Abe. (*Tetsu to Hagane*, 1958, **44,** Mar., 270–272).—K. E. J.

Studies on Fire Cracks. II. J. Watanabe. (*Tetsu to Hagane*, 1958, **44,** Mar., 381–382). The effects of temperature and chemical composition on fire-cracking are discussed.

PRODUCTION OF FERRO-ALLOYS

The Production in a Vacuum of Carbon-free Ferro-Chromium by Decarburization of High-Carbon Ferro-Chromium. S. V. Bezobrazov. (*Primenenie Vakuuma v Metallurgii*, 1958, 155–162). It is shown that ferrochromium containing 0·01–0·03%C can be obtained using Cr_2O_3, chrome ore, quartzite or NiO at 1100–1250° C and 0·05–0·01 mm. The Cr recovery is also improved.

FOUNDRY PRACTICE

Advances in Foundry Practice Made During 1957. P. A. Heller. (*Stahl Eisen*, 1958, **78**, Dec. 25, 1898–1905). A comprehensive review under the headings: Structure and properties; Melting practice; moulding shop and fettling practice; and general. (137 references).—T. G.

Recent Progress in Metal Founding. M. Hamasumi. (*Nippon Kinzoku*, 1957, **21**, June, M1–M18). Recent progress in sand moulding is reviewed, particularly the chemical aspects. Subjects treated are moulding sands, clays, binders and clay minerals, core oils, shell-moulding, lost-wax moulding and the CO_2 process. (20 references).—K. E. J.

25th International Foundry Congress. (*Liège and Brussels*, 1958, pp. 735). **Men and Foundry Work.** H. Scholz. (3–19). [In German]. The work of the Max Planck Institute of Labour Physiology is described. A general study of working conditions in old and modern foundries has been made and working load evaluated. The main reasons for energy overloads are given and directions for improvement are indicated. **The Growth in the Production of Grey Iron Castings and Some Factors Affecting It.** L. Villner. (22–41). [In English]. Statistical studies for Sweden Germany, Great Britain and the U.S. are presented showing a lag behind the levels of total industrial output. Factors in the low growth rate discussed including improvements giving lighter castings and so smaller tonnage and competition with other materials and welding and the use of sheet metals. **Current Research Trends in the Foundry.** M. G. Blanc. (44–63). [In French]. A general review in many fields with 139 refs. **Gases in Cast Iron.** B. Marincek and H. Feichtinger. (66–82). [In German]. The preparation of test pieces, which is critical, the apparatus used and its operation are described. The apparatus should work with a low blank and degassing should be continued up to ~ 2000° C. Many results are given and discussed. **Contribution to the Effect of Ladle Additions on Cast Iron.** W. Patterson. (85–105). [In German]. The concepts of "degree of normality" and "relative hardness" are put forward for the evaluation of the quality of grey iron. The ratio of these is suggested as an index of quality. It is high for irons containing mainly "A" type graphite formed in heavily nucleated melts and it is promoted by "inoculating" ladle additions. Heat treatment to prevent the formation of other types and to form new nuclei is recommended. **Results of Investigations into Non-Magnetic Ni–Cu–Mn Cast Irons.** A. De Sy and J. Van Eeghem. (108–123). [In French]. Tensile strength is much improved by nodularizing treatment with Ni–Mg or Mischmetal or both. High Mg contents tend to precipitate a Cu phase. The spheroidal graphite irons are tougher, but have greater permeability. **Grain Size of Grey Cast Iron.** J. S. Abcouwer. (242–247). [In French]. An expression is given for rate of solidification and its relation to grain size. An attempt is then made to relate this to the size of the eutectic cells. An exact solution of the heat transmission problem is added, also an approximation relating thickness of actual and imaginary walls in sand moulds. **Determination of the Sections of Feeders for Castings of All Shapes and Sizes in Iron Cast in All Types of Sand, with Examples.** (250–274). C. Trenckle. [In French]. All tables, graphs and formulæ for time of filling and section are given with a highly condensed account of the work done. **Considerations on the Calculation of the Pressures Exerted during Pouring on the Mould Walls and Cores.** R. Namur. (279–286). [In French]. Impingement and cope-lifting forces and thrust on the cores are formulated. **Metallic Chaplets.** F. Kinet. (288–306). [In French]. A review of patented designs and those typically in use is given. Difficulties with and defects arising from their use are discussed and their behaviour and effect on the surrounding metal is studied metallographically. **Cold and Hot Strength of Sands for Moulding and Core Making and of Chaplets.** R. Collette, F. Gaty and R. Namur. (308–321). [In French]. Tests up to 1200° C have been carried out to classify the sands for various foundry purposes. Resistance to compression was measured up to the temperature at which a shrinkage can be observed. A penetration test was developed for sand and for chaplets and resistance to buckling and shear was noted. The temperatures and pressures attained in the mould were also measured. The function of coatings is also discussed and further work suggested. **The Relation of Engineering Performance of Castings to Metal Structure.** R. A. Flinn. (326–341). [In English]. Mechanical and general engineering properties, wear and abrasion, and heat and corrosion resistance are illustrated with examples. The engineering performance is shown to depend uniquely on structure other variables being kept constant. The improvements to be effected by study of the micro-constituents are indicated. **A Study of the Effect of Copper on Cast Iron and Steel.** P. Van Bleyenberghe and R. Coussement. (415–425). [In French]. The properties of 3%Cu grey iron suitable for railway use, of chill cast grey iron with 1·5% Cu and reduced Si showing good wearing properties; of hard steel with 2%Cu for ball-mill balls with an austenitic structure and the fluidity properties of 1·5%Cu steels for their sections are given. **Graphitisation in Cast Iron–Carbon Alloys.** A. Wittmoser. (461–482). [In German]. Graphite formation is considered and related to particle form and location in the matrix. Five types are defined into which all the structures can be classified. The mode of formation of graphite is found to be very much the same in all cases, differing only in that formed in the melt or in solid solution, in general the former is flake and the latter spheroidal. Mechanism is considered. **The Effect of Various Deoxidizers on Cast Steel.** C. E. Sims and C. W. Briggs. (500–514). [In English]. The kinetic data for deoxidation and equilibrium conditions are briefly indicated and the effects of Mn, Al, Ti, Zr, Mischmetal and Se and the factors preventing the use of Ca, Mg, Na, Ba, K and Li are noted. Work on high-N steel is mentioned. **Application in the Steel Foundry of Blind Side Feeders with an Exothermic Coating.** E. Ney. (517–542). [In French]. A form of a cylinder attached to a hemisphere is advocated, the cylindrical portion only being surrounded with exothermic composition. Economies of 40% in feeder size are claimed. **The Use of Exothermic Feeding Compositions in the Production of Steel Castings.** D. H. Snelson. (544–563). [In English]. Feeding characteristics of heads are investigated and the principle of head design discussed. A classification of castings based on solidification time, has given a relationship between minimum head diameter and section size for simple sections. Pouring temperature and running distance are discussed with regard to the extension of the expression to much larger castings of the same basic section. **Condition of Moulding Material and Casting Surface.** P. Schneider. (597–613). [In German]. A pneumatic device for measuring surface roughness is described and surface condition is related to the surface tension force of the liquid metal. Gas permeability of the sand is also related to surface roughness even with different types of sand, cast quality improving with increasing milling time and hardness of ramming in synthetic sands. The linear relationship holds only for sands compacted at the same moisture content. Excess humidity gives rough castings and roughness is reduced by coal dust or pelleted pitch additions and also depends on casting temperature. The reduction of surface tension in cast iron brought about by S leads to increase in roughness. At lower surface tensions the effect of ramming is less. **The Effect of the Metal Stream on the Inner Surface of the Sand Mould.** J. Szreniawski. (617–637). [In German]. The effect during filling and up to the formation of a solid skin was studied. Three types of flow which destroy the surface are recognized: impact, turbulent and jet. A method for determining the endurance of the mould or core under attack by the metal stream is described. The ordinary tests for sand evaluation are shown to be unsatisfactory. Practical conclusions are worked out. **The Properties and Testing of Materials Used in the CO_2 Process.** D. A. Taylor. (641–661). [In English]. Testing methods at room and high temperatures are described and the effects of silica: soda ratio, viscosity, time, gassing temperature and CO_2 concentration were observed. Dry silicate and damp sand could be substituted for dry sand and silicate solution. Diluted CO_2 is shown to be economical and reclaimed sand can sometimes be partly substituted for new. The effect of this reclaimed sand or clay-bonded sand was also investigated. High temperature tests showed gas evolution to be low even in presence of organic materials. The transformation to cristobalite is shown to be complete in a few min at 1300° C but can be retarded by small amounts of powdered Al_2O_3. Core breakdown is also considered and inorganic materials were found which facilitate this without reduction of room-temperature strength. **Metallurgical Technique and Application of the Alloy Iron Castings for Diesel Engine Parts.** B. V. Mahabale. (664–669). [In English]. **Investigations of Basic Refractory Materials for the Cupola.** B. Sochor. (673–691). [In German]. Bricks and ramming materials were examined in a cold blast cupola keeping conditions as constant as possible. Magnesite LID was the best material tried, chrome–magnesite and periclase–forsterite showed no advantages. Materials in current production proved good enough and withstood temperature changes and the steam produced by dropping the bottom and quenching the drop-coke. Consumption of refractories and costs are discussed. Operation showed savings even with 25% substitution of steel scrap for pig iron. **Dust Removal from Cupolas.** R. Goenaga. (694–706). [In French]. Type of dust, dust content and type of gas are considered in turn and the difference between the grit from cold blast and the fine particles from hot blast working is noted. Types of dust arrestors for both are described. The mechanics of suspensions are given in an appendix. **Review and Development of Cupola Water-Cooling Systems.** C. Longaretti and C. Pensotti. (708–735). The development and design of water-cooled cupolas are considered and practical information on cooling systems is presented.

Rebuilding of Union Iron Works. (*Foundry Trade J.*, 1958, **105**, Dec. 4, 679–682). An illustrated account of the premises of John Hall & Son, (Oldham) Ltd. newly extended and rebuilt.

Steelworks Extension. (*Iron Steel*, 1958, **31**, Nov., 525–527). An account is given of the concentration of production by Arthur Balfour & Co. Ltd. on their Greenland Road site, with particular reference to the characteristics and performance of a 600 kW high-frequency melting unit, and the reduction of air pollution.

Visit to The Muovo Pignone Foundry. (*Fonderia Ital.*, 1958, **7**, Oct., 387–391). The article describes in some detail a visit to the modern foundry of The Soc. Muovo Pignone. The foundry is equipped with up-to-date cupola plant, mechanical handling devices, a Fenwick sand preparation installation, an 800 Kw induction furnace and the usual ancillary services and laboratories.

The Economy of Production in Foundries: The Production Process. A. Naundorf and G. Schmidt. (*Giessereitechnik*, 1958, **4**, Oct., 243–249). A note on the reorganization of factories taken over by the State.

The Rational Modernisation of Foundries. A. M. Plešinger. (*Giessereitechn.*, 1958, **4**, Nov., 275–282). The application of modernization in Czech foundries, and the method adopted to determine the principles of a rational economy are described.

The Use of Ferro-Alloys Enables Small Iron Foundries to Meet the Exacting Requirements of Customers. (*Fonderia*, 1958, **7**, Dec., 533–536). Ferro-silicon, ferro-manganese, ferro-chrome and ferro-nickel are now indispensible auxiliaries to every foundry. The article reviews how those alloys can be used to improve foundry work.—M. D. J. B.

The Inoculation of Solidifying Iron and Steel Castings by means of Vibration. J. H. Gittus. (*JISI*, 1959, **192**, June, 118–131). [This issue].

Practical Installation of Statistical Control in the Steel Foundry. P. Destable. (*Mét. Constr. Méc.*, 1958, **90**, Nov., 849–855; Dec., 931–937). This article deals with the principle of statistical control as applied to the theory and practical application of the analysis of variance. Methods of determining suitable sampling intervals in connection with the large-scale production of components and the application of statistical control are discussed.

Note for Modern Foundry Managers. G. Barchiesi. (*Fonderia Ital.*, 1958, **7**, Dec., 485–496). The author lists the various technical and personal qualities which are asked for in the modern foundry manager and goes on to suggest means which will enable him to keep abreast of developments while keeping in daily touch with the more practical problems of running a foundry.

Control of Foundry Dust. L. Hirsch. (*Koh. Lapok*, Ontöde, 1958, **9**, Oct.-Nov., 246–249). Silicosis is increased by the time of exposure to a foundry dust of higher SiO_2 content and a greater concentration of 0·4–5 micron particles. Thus, for prevention of this illness, the use of steel shot, instead of sand blast, and application of moulding materials without, or with only low SiO_2 content are suggested. An adequate ventilation is also important; however, it can only be achieved with high cost and difficulty. Up-to-date testing of foundry dust is also described in the paper.—P. K.

Foundry Ventilation. K. Nilsson and Y. Bovin. (*Fond. Belge*, 1958, **28**, Nov., 317–331, 339). The general principles of foundry ventilation are described, with special reference to mechanized foundries, several examples are given, and economic considerations are discussed.

VACUUM METALLURGY

Vacuum Melting. H. Kjollesdal. (*Tidsskr. Kjemi Bergv. Met.*, 1958, **18**, (9), 141–147). The physical metallurgy and theory of the process are given and the improved products produced by the process are reviewed.

Vacuum Melting Furnaces. H. Kjollesdal. (*Tidsskr. Kjemi, Bergv. Met.*, 1958, **18**, (8), 125–130). The construction and operation of resistance, induction and arc furnaces for melting metals in a vacuum are reviewed, with particular reference to arc furnaces. (29 refs.).

Tinken Now Operates Consumable Electrode Vacuum Arc Furnace. J. E. Fick. *Blast Furn. Steel Plant*, 1958, **46**, Dec., 1292–1293). The principle and method of operation of this furnace are described. The furnace capacity is 200 t of alloy steel per month.

Vacuum Arc Melting and Experience with a New Installation. R. Kieffer and W. Wirth. (**Data of High-Vacuum Technology and the Physics of Thin Layers*, 1957, (*Wissenschaftliche Verlagsgesellschaft m.b.H.*, 178–183). An account of the Metallwerk Plansee unit at Reutte/Tylor is given. Metals such as W, Mo, Ta, Nb, Ti and Zr are treated.

Vacuum Heat-Treating. R. L. Hoff. (*Met. Treat.*, 1958, **9**, Sept.-Oct., 4–6, 58–61). The advantages and limitations of vacuum heat-treatment are discussed and advice is offered on the required equipment.—T. G.

The Vacuum Deoxidation and Desulphurization of Transformer Steel. A. M. Samarin. (*From "*The Use of Vacuum in Steel Melting Processes*," Moscow, 1957, 3–14). Vacuum melting conditions and the kinetics of decarburization and the process of desulphurization are discussed and recommendations are made.

The Desulphurisation and Deoxidation of High-Purity Iron by the Vacuum-Fusion Process. W. Jäniche and H. Beck. (*Arch. Eisenh.*, 1958, **29**, Oct., 631–642). Experiments are described for the production of high-purity iron by the desulphurization and deoxidation under vacuum of electrolytic iron, desulphurization being carried out by the volatilization of the sulphides of added metals.

On the Vacuum Casting of Steel. T. Asakuma. (*Tetsu to Hagane*, 1958, **44**, Mar., 329–331). Various operating conditions are described and analysed, and comparisons are made between the hydrogen, oxygen and nitrogen contents of air- and vacuum-poured steel.—K. E. J.

The Metallurgy of the Production of High-Purity Iron. B. Vécsey. (*Koh. Lapok*, 1958, **13**, Aug, 357–361; Sept. 406–409). In the second part of the paper the author reviews the production of high-purity iron: (*a*) in hydrogen, and under high vacuum. Hungarian experiments on sponge-iron production are also described. In the concluding part of the paper, further methods of production of high-purity iron in a high vacuum are reviewed. In these methods, H_2 or C is used for deoxidation of electrolytic or carbonyl iron.—P. K.

REHEATING FURNACES AND SOAKING PITS

Rapid Heating of Ingots for Working. S. Bala. (*Prace Inst. Hutn.*, 1958, (5), 261–268). Trials on the charging of cold ingots into furnaces slightly above working temperature were made and rapid and slow heating were compared for 0·6%C steel and 18–8 heat-resisting steels, high-Mn and Invar on ingots of 125–8500 Kg. Most grades were found to be unaffected by rapid heating, but H18N10M with 0·4–0·5%Mn, 0·6%Si, ~0·036%S, 0·09%P, ~18·5%Cr, ~9·1% Ni and 2·46%Mo and H25N20S2 with 0·11% C, 0·98%Mn, 0·68%Si, 0·028%S, 0·012%P, 24·5%Cr and 21·42%Ni were unsuitable.

Fuel Economy in Forging Furnaces. F. P. Merkle. (*Ing. c. Indust.*, 1958, June, 85–87). Modifications in the design of the furnace, in particular the use of a flat roof, have led to substantial fuel economies.

Heating of Steel Billets before Rolling. H. Müller and W. Annen. (*Elektrowärme*, 1958, **16**, Oct., 366–369; Dec., 422–427). Direct resistance heating gave improved quality. Comparisons are made with fuel-burning, resistance and induction furnaces and an historical review of the method is included for the last 10 years. The structures obtained are illustrated and the advantages noted. Special reference is made to shipbuilding.

Experience Obtained with Oil-Fired Pusher-Type Furnaces. R. Müller and F. Hollweger. (**Stahl Eisen*, 1958, **78**, Nov. 13, 1676–1678). A pusher-type furnace for re-heating high-grade steels was converted from gas-firing to oil-firing. Details of the burners and the furnace are given. If the oil is properly atomized no deleterious effect on the steel billets was observed. The initially high wear of the bricks could be eliminated.—T. G.

Modern Soaking Pit Installation at Allegheny Ludlum Steel Plant. (*Ind. Heat.*, 1958, **25**, Aug., 1578–1580). A brief account of a new gas-fired installation.

Soaking Pits with a High Velocity Combustion System. D. C. Haney. (*Iron Steel Eng.*, 1958, **35**, Nov., 82–89). The result of 12 month's operation have shown that the replacement of 8 batteries of four small, gas-fired regenerative pits by 2 batteries of three larger one-way, top-fired pits, each with a separate recuperator has given satisfactory operation and improved rate of heating, without requiring additional building space.

Effect of the Sulphur in the Furnace Atmosphere on the Hot-Workability of Steel. II. T. Morishima. (*Tetsu to Hagane*, 1958, **44**, Mar., 392–393).—K. E. J.

Research and Development Engineering Corporation for Ferrous Metallurgy. (*Aciers Fins. Spéc.*, 1958, Dec., 7–11). An account of SERSID with a briefly annotated list of work in progress, mainly on soaking pits and blooming mills. A standard slag ladle is shown.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

No Waiting in This Heat-Treat Line. L. N. Everitt and C. C. Sykes. (*Met. Prog.*, 1958, **74**, Dec., 75–79). The heat-treating department at the Columbus, Ohio, plant of the Timken Roller Bearing Co. functions as a single machine to process automatically five standard lines of railroad roller bearings. A special feature of the plant, which is described and illustrated, is the rotary furnace.—T. G.

New 32-ft. Mobile Gantry Furnace treats Large Polaris Missile Parts. F. M. Arnold. (*Western Metalw.*, 1958, Oct., 46–47). The heat treatment of large missile components requires extra large furnaces. The unit described is a gantry-type, bottom loading, hardening furnace which provides facilities for tempering, generating an endothermic atmosphere, oil quenching and vapour degreasing. Working dimensions are 5 ft × 14 ft. Temperature range is up to 1850° F and the unit is fired with natural gas. The charge is placed in a pit from whence it is pulled up into the furnace by stainless steel chains.—R. S.

Mechanized Austempering of Steel Harrow Discs. (*Met. Prog.*, 1958, **74**, Sept., 78–80). Automatic austempering has almost doubled the production of these discs at International Harvester Co. of Canada. The bainitic structure obtained by this process prevents directional cracking. The heat-treatment operation which is described is fully automatic.

The Kinetics of Martensite Tempering. O. Krisement. (*Arch. Eisenhütt.*, 1958, **29**, Nov., 723–729). A microcalorimetric method has been used to determine isothermal martensite tempering in a steel with 1·03%C at temperatures from room temperature to 260° C.—L. J. L.

FORGING, STAMPING, DRAWING AND PRESSING

Short-Run Forging Can Be Economic. E. M. Gardner. *Metalw. Prod.*, 1959, **103**, Jan. 9, 53–56). Methods sometimes applicable to reduce die costs are given. Also the cost of forging components with irregular internal surfaces or to close tolerances can sometimes be reduced. Examples are given of the production of a gate valve fork, a tubular scaffolding socket and the use of split dies for upsetting.

Forging Blooms from Ingots. J. E. Decker. (*Met. Prog.*, 1958, **74**, Sept., 71–73). If ingots are to be rolled the taper must be slight only, but if they are forged they can be patterned for elimination of segregation, i.e. they can be heavily tapered. During the upsetting operation, the piped zone is separated from the sound metal. The blooms so produced are particularly sound.—T. G.

Forging and Heat Treating Practices for Armco 17-7 PH Stainless Steel. W. J. Davison. (*Met. Treating*, 1958, **9**, Nov.-Dec., 6–8). Treatment of the material to produce condition A by solution treatment, condition T by transformation and conditions RH-950 and TH 1050 by ageing are described and recommendations for forging are given.

Use of Hammers and Presses Instead of Roughing Mills in Installations Producing Plain Carbon Steels. E. de Séze and J. Courthéoux. (*Problemas de la Industria Siderúrgica y de Transformación de Hierro y Acero en América Latina*. 1957, **2**, 199–203). The use of a forging press instead of a primary rolling mill to deal with increased capacity is described, and operational details are given.

Contributions and Progress in Modern Processes for the Manufacture of Seamless Tubes. A. Calmes and T. Passoni. (204–207).

Equipment and processes for manufacturing seamless tube are described and illustrated.

Prevention of Longitudinal Surface Crack Formation of Small Forging Ingots. T. Kamoshida. (*Tetsu to Hagane*, 1958, **44**, Mar., 320–321). It is shown that there is a critical casting temp., calculated as the temp. of steel in the ladle just after tapping minus 4 deg. C/min × (tap-cast time in min). Cracking is liable to occur above this temp., the variation of which with C content is shown.

Forgeability of a Transformation-free Alloy Ingot. II. Relation between Tensile Properties, Bendability and As-cast Structures of Timken 16-25-6. T. Yamane. (*Tetsu to Hagane*, 1958, **44**, Mar., 432–433).—K. E. J.

The Forging of Heat Resistant Metals. T. Jordan. (*Werkstatt. Maschin.*, 1958, **48**, Oct., 567–568). A report of a paper with the above title given at the Conference on Technology of Engineering Manufacture in London, March, 1958.

Effect of Forging Ratio on the Behaviour of Cementite in Ball Bearing Steel. G. Tasaka. (*Tetsu to Hagane*, 1958, **44**, March, 416–417).

The Temperatures Arising in Upsetting Tool Faces and Dies in Forging Cylindrical Samples from Steel and Pantal. G. Beck. (*Werkstatt. Maschin.*, 1958, **48**, Oct., 561–567). The experimental results of temperature measurements in the tool, in the hot upsetting and drop forging of steel are described, and general considerations regarding temperature changes in the tool are discussed.

Compression in Pressing Operations. J. Guyot and P. Mercier. (*Rev. Mét.*, 1958, **55**, Sept., 801–814). A test is described, with examples, to investigate the behaviour of sheet under compression. The test results show no correlation with the coefficients for elongation tests.

Crinkle Formation on Preformed Sheet-Metal Parts. G. Oehler. (*Stahl Eisen*, 1959, **79**, Jan. 8, 45–46). Sheet metal parts that were subjected to further deformation showed crinkles if the hardness exceeded a certain limit, no difference being found in the microstructure of the two materials. The use of a lubricant may avoid this defect.—T. G.

Effect of Carbon Content, Degree of Cold Working and Heat-Treatment on the Properties of Deep-Drawing Strip Steel Killed with Aluminium. K. G. Schmitt-Thomas, H. Borchers and V. Seul. (*Stahl Eisen*, 1958, **78**, Dec. 11, 1798–1808). A practical and theoretical study of the interrelation of carbon content, degree of hot and cold working and of the various heat-treatments on the quality and consistency of high-grade deep-drawing strip steel. The results of the very comprehensive trials are reported in detail and an attempt is made to interpret the results by current dislocation theories. (39 ref.)—T. G.

The Hydraulic 25-t Rod Drawing Bench of the Max-Planck-Institut für Eisenforschung, and Its Application. W. Lueg and O. Pawelski. (*Stahl Eisen*, 1958, **78**, Dec. 11, 1812–1815). The new drawing bench is described in detail with particular emphasis on the hydraulic controls, and on the pushing-in devices. As the bench is intended for scientific investigations, it is equipped with extensive measuring apparatus. A short review of the work carried out so far on this bench is included.—T. G.

Lubrication in High-Speed Wire Drawing. L. Mankher. (*Koh. Lapok*, 1958, **13**, August, 374–379). Lubrication in high-speed wire drawing is discussed, and the necessary conditions are given for efficient fast drawing.

Effect of a Surface Pass and of Straightening on Residual Stresses in Steel Wire. H. Bühler and G. Altmeyer. (*Stahl Eisen*, 1958, **78**, Dec. 11, 1822–1827). The principle of the test and its performance are described. A surface pass or re-draw with a reduction of 1·3% reduces the residual stresses by 35%, whereas straightening increases the diameter by 1·3% and reduces the stresses in the outer zones by 50%, the stresses are almost eliminated for a diameter increase of 2·35%. Tempering further reduces the stresses the higher the temperature for a given holding time.—T. G.

Drop in Tensile Strength of Steel Wire as a Consequence of Drawing. T. Nishioka. (*Nippon Kinzoku*, 1958, **22**, Jan., 26–30). Four steel wires, ranging from mild steel to 0·81%C steel, air or lead patented, and hard drawn by conventional methods, were then given an additional light pass, as a result of which the tensile strength was reduced, the elongation increased, and the performance in the torsion test improved. This effect was examined in greater detail as a function of the reduction and die angle in the light pass and the total preceding reduction and number of passes. The results are plotted in graphs with legends in German.—J. G. W.

The Bending of Drawn Steel Wire. T. Nishioka. (*Nippon Kinzoku*, 1957, **21**, July, 433–436). [In Japanese, with summary in German].—K. E. J.

Investigation of the Properties of the Surface Layer in the Case of Chipless Shaping of Steel with Various Amounts of Carbide Phase. I. L. Mirkin and T. A. Sirenko. (*Metall. Obra. Met.*, 1958, (9), 29–33). Metal shaped by piercing in tube manufacture was examined. Steel 30 with 0·32%C and about 4·8% cementite and steel U8 with 0·78%C and ~12% cementite were used and these were hardened and tempered to produce equal grain sizes. Microhardness in depth is plotted showing the surface strength to be about twice that of the original metal. The degree of hardening, depth of deformed layer and carbon content showed linear relationships. The best steel for piercing appeared to be steel 50 with 0·49%C, 0·56%Mn, 0·35%Si, 0·02%P and 0·026%S.

ROLLING MILL PRACTICE

Study of Rolling Mill Load Performance. S. Nakaya. (*Tetsu to Hagane*, 1958, **44**, Mar., 384–386). Relationships between rolling ratio and various energy input parameters (for different types of steel), the distribution of energy usage in blooming and finishing mills, friction coefficients, etc. are discussed.

Determination of Roll Pressure and Bar Forces in a Stiefel Tube Mill. (*Neue Hütte*, 1958, **3**, Dec., 758–763). These quantities were measured during the rolling of pre-pierced billets 94–98 mm in dia. × 7·5–10 mm wall thickness to 86 mm × 3, 3·5 and 4 mm, using different types of mandrel. The method of measurement is described in detail, and the results are discussed.

Effect of Forward and Back Tension on Rolling Force. P. Funke jun. (*Stahl Eisen*, 1958, **78**, Dec. 11, 1832–1834). A review of theories and formulæ published recently on the determination of the rolling force from forward and back tension is presented and the individual methods discussed.—T. G.

Dynamic Loads in Rolling Mill Machinery. S. N. Koschewnikow. (*Neue Hütte*, 1958, **3**, Nov., 655–665). The origins of dynamic loads in rolling mill machinery are discussed; a method of calculation is described; an electronic computer method of solving problems of design is reported.—L. J. L.

Electron-Microstructure of the Working Roll for Cold Rolling. IV. T. Ando. (*Tetsu to Hagane*, 1958, **44**, Mar., 456–458).—K. E. J.

Maintenance of Backup Roll Bearings in Strip Mills. W. M. Lewis. (*Iron Steel Eng.*, 1958, **35**, Nov., 115–122). A detailed description is given of the maintenance and assembly of sleeve-type "babitted" bearings for backing rolls, reference being made to checking the lubricant and keeping maintenance records.

Metal Bearings with Pure Fluid Lubrication for Roll Necks. I.—Bearing Unit with Bush and Conical Neck. B. Sprenger. (**Stahl Eisen*, 1958, **78**, Dec. 25, 1853–1861). The principles, design and construction of full-flow bearings for roll necks are described. **II.—Roll Neck Bearings with Journal on the Roll Neck Designed for the Flow of Large Quantities of Oil.** W. Müllenbach. (1861–1865). Principles and design of full-flow bearings and their advantages are discussed. **III.—Roll Neck Bearings for Full-Flow Bearings of Simple Design.** J. Fröhling. (1865–1867). A simple and rather inexpensive full-flow bearing design is described. The special feature of it is the careful ventilation of the gaps and their connection with the oil supply so that no air can be entrained into the bearing part.—T. G.

The New Medium-section Mill at the Cleveland Works of Dorman Long (Steel) Ltd. V. Harrison and V. Stephenson. (*JISI*, 1959, **192**, June, 132–142). [This issue].

New Slabbing Mill. (*Iron Steel*, 1958, **31**, Nov., 535–537). A description of the slabbing mill opened by B.H.P. at their Port Kembla works.

American Steel and Wire's Newest Rod Mill. R. R. Snow. (*Blast Furn. Steel Plant*, 1958, **46**, Dec., 1305–1306; 1330–1331, 1339). An account is given of the layout and operation of the new rod mill at the Cuyahoga Works of United States Steel Corporation.

High Strength Steel is Produced in Wide Sheets. (*Iron Steel Eng.*, 1958, **35**, Nov., 141). Lukens Steel Co. have produced by pack rolling high-strength steel sheet 160 in. wide, using their 206-in. plate mill. The steel is intended for use in rocket motors.

Planning Heavy and Medium Plate Mills. W. Müllenbach. (*Demag News*, 1957, (149), 23–31). Four-high mills are discussed and various combinations of rolling units are considered and shown in general plan.

Louisville, Ohio, Plant of J. & L. is Ready for Full Operation. (*Iron Steel Eng.*, 1958, **35**, Nov., 138–139). An account is given of the layout and capacity of Jones & Laughlin's new plant for the production of stainless steel sheet and strip.

The Shape of Rolls for the Hot-Rolling of Sheet and Wide Strip. J. Mercader. (*Koh. Lapok*, 1958, **13**, July, 317–321). Methods of calculation are given in order to determine the shape and dimensions of the roll surface for hot-rolling of sheet and wide strip.—P. K.

New Brinsworth Mill of Steel, Peech and Tozer. (*Iron Coal Trades Rev.*, 1959, **178**, Jan. 2, 21–27). An illustrated account of inception and equipment.

Installation and Operation of the Reversing Hot Strip Mill. G. Buch. (**Blech*, 1957, **4**, (11), 81–85). A description of a modern installation with a brief historical introduction.

Morg Årdshammars System Rolling Train. M. Shobu. (*Tetsu to Hagane*, 1958, **44**, May, 571–582). [In Japanese]. A review, with 43 references.—K. E. J.

Development of a Four-Roll Finishing Stand to a Two-Stand Tandem Mill. H. Bischoff. (*Demag Nachr.*, 1958, (154), 30–32). The modification of a 4-high stand to a tandem mill, with the addition of a further finishing stand to improve production and quality in a tinplate mill is described.

Fully Continuous Narrow-Strip and Wire-Rod Mill. L. Wegmann. (*Demag News*, 1957, (148), 16–29). A description of the mill erected for ARBED in Esch-Luxembourg. Design, operation, drives, conveyors, electrical equipment and controls are described and illustrated. It is planned to roll 35 t narrow strip and 20 tons wire rod 5–12 mm dia. per h.

Medium Width Steel Strip. (*Engineering*, 1959, **187**, Jan. 2, 22–23). A description of the new Brinsworth Mill.

Effect of Rolling Conditions on the Properties of Low-Carbon Hot Strip. II.—Mechanical Properties and Structure. W. Dahl and W. Lueg. (*Stahl Eisen*, 1958, **78**, Dec. 11, 1793–1798). The mechanical properties of the strip were studied after cold-rolling to 80%. Strip rolled at temperatures above A_3 show higher strength than strip rolled below this temperature. This behaviour is attributed to a smaller grain size of strip rolled above A_3. The differences in strength remain in spite of intermediate annealings during all cold-rolling operations. Strength is higher in the transverse direction than in the rolling direction, i.e. grain elongation imposed during hot-rolling is not eliminated by the intermediate annealings. However, the results vary as the weight of the coil, as cooling rate and hence precipitation is slower for heavier coils than for lighter coils.—T. G.

Automatic Numerical Data Logging and Processing in the Steel Industry. R. M. Sills and G. E. Terwilliger. (*Iron Steel Eng.*,

1958, **35**, Nov., 101–109). Data processing systems and devices are described, and their application to a strip mill and tinning line outlined.

Cold-Rolling Mills for Narrow and Medium Strip. C. Volkhausen. (**Blech*, 1957, **4**, Nov., 88–92). Frequent changes of dimensions, type and quantity of product may be required from these mills. Actual installations are considered and a combined cold-rolling plant with a combination roll train and with multi-purpose assembly in the same stands is described.

Study on the Rolling of Metals and Alloys by a Sendzimir Reversing Cold Strip Mill. I. Study of the Pattern of Waves Appearing on the Metal Foils. E. Tanaka and T. Yoshiki. (*Nippon Kinzoku*, 1956, **20**, Nov., 597–600). In the rolling of metal foil by the ZR 32–4 Sendzimir mill, regularly spaced waves inclined to the rolling surface were sometimes found. These depended on the front tension, and could be suppressed above a critical tension. The waves are a type of centre buckling, but are not of "stretcher strain" or "herring-bone" types.—K. E. J.

Fundamental Aspects of Scale on Mild-steel Strip. S. Garber. (*JISI*, 1959, **192**, June, 153–160). [This issue].

Anzin Works of the Tubes Division of the Lorraine-Escaut Group. (*Aciers Fins Spéc.*, 1958, Dec. 99–104). A brief account of the growth and present equipment of the works and the steels used.

Studies on the Rolling of Seamless Steel Tubes. III. Effect of Rolling Condition on the Various Loads of a Plug Mill. K. Sato. (*Tetsu to Hagane*, 1958, **44**, Mar., 386–388). The effects of lubricants, types of steel rolled, rolling temp. and rolling pressure are discussed.—K. E. J.

Relation between Quality of Tube Rounds Made from a Rimmed Steel Ingot and Inner Surface Defects of Seamless Steel Tube. II. Effects of Sand Marks and Sulphur Segregation on Inner Surface Defects. N. Eguchi. (*Tetsu to Hagane*, 1958, **44**, Mar., 379–380). Relationships are shown between inner surface defects and sulphur segregation and Mn/S ratio in the round, and black spots are analysed, to determine the effects of the Mn/S ratio.

Hungarian Steel-Tube Production. J. Ruhmann. (*Koh. Lapok*, 1958, **13**, Aug., 362–366; Sept., 422–426). In the first part of the paper the author reviews the following methods of steel-tube making: (1) Mannesmann, (2) Stiefel, (3) Erhardt, (4) Continuous rolling, (5) Extrusion, (6) Welding. In the second part, the position of Hungarian steel-tube production is reported and compared with the World production.—P. K.

Modern Rolling Mill Drives. K. Breuer. (*Demag Nachr.*, 1958, (154), 1–15). A survey is given of the modern development of main drives; a general outline of the principal features of modern blooming and slabbing, medium and light finishing trains and continuous mills, including wire mills, is followed by a description, with illustrated examples of features of the drives and their lubrication.

Production Control in Rolling Mills with the Aid of Intercommunication and Signalling Systems. H. Brosch and H. Waburek. (**Stahl Eisen*, 1959, **79**, Jan. 8, 23–32). The various apparatus used for intercommunication and signalling in rolling mills are described and their merits discussed and analysed with a view to further developments.—T. G.

Computer Speeds up Measurement of Steel Tubing. (*Western Metalw.*, 1958, Oct., 43). The article describes the use of a computer for the accurate measurement of tube length. The "linear encoder" involves a computer, memory drum and hand grip and measurements are recorded by an automatic typewriter.—R. S.

Weighing Machines for Rolling Mills. H. Schulten. (**Blech*, 1957, **4**, Nov., 92–98). Examples are given showing that by collaboration between the weighing machine designer and the works engineers the weighing device can be fitted into the works cycle without causing delays or excessive costs.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

The Gas Turbine in the Iron and Steel Industry. M. E. Aguet. (*Revue M Tijdschrift*, 1958, **4**, (3), 147–163). The evolution of the gas turbine in its application to the iron and steel industry is described, and illustrated by a detailed account of some examples. Future prospects and probable lines of development in design and fuel economy are dealt with.

Another Turbogenerator Failure. R. J. Landrum. (*Met. Prog.*, 1958, **74**, Sept., 91–94). The failure and its causes of a 3000-kW. turbogenerator at the du Pont Co.'s plant at Old Hickory, Tenn., are described. The generator was installed in 1934 and overspeeded immediately before the failure. From metallurgical evidence it is concluded that the damage originated in the rupture of a retaining ring.—T. G.

Structural Steel Handling with Mobile Equipment. P. F. Walker. (*Iron Steel Eng.*, 1958, **35**, Nov., 110–114). The use of lift trucks at the Bethlehem plant of Bethlehem Steel Co. for loading for despatch 19 000 t of structural steel parts a month is described.

Electrical Advances Can Reduce Installed Costs. E. E. Vonada. (*Iron Steel Eng.*, 1958, **35**, Nov., 90–96). A general survey is made of new electrical installations installed in modern steel mill developments, with an assessment of costs.

Tackling Water Pollution. E. G. Paulson and E. P. Partridge. (*Iron Steel Eng.*, 1958, **35**, Nov., 123–129). The necessity for conserving water supplies in the U.S.A. is emphasized and methods of re-using and decontaminating water for industrial purposes are described. (16 refs.).

Water Economy in Iron and Steel Works Undertakings. F. Wesemann. (**Jernkontorets Teknista Diskussionmote;* lecture, May 31st, 1958). A discussion of economy in water use, water reconditioning and effluent treatment and volume reduction is presented.

WELDING AND FLAME-CUTTING

Welding Metallurgy, based on Papers Presented to the Public Session of the I.I.W., Essen, July 1st, 1957. H. Granjon. (*Soud. Techn. Connexes*, 1958, **12**, March-April, 85–100). The author summarizes the 26 papers presented at Essen under the following headings: properties of the molten zone including welding atmosphere, gases, effect of hydrogen; behaviour of the base metal (ferrous and non-ferrous); metallurgy of the weld area.—R. P.

Recommended Practice for Flash Butt Welding. (*Rivista Ital. Soldatura*, 1958, **10**, Aug., 147–153). [In Italian]. The paper defines the geometrical, electrical and mechanical variables of flash butt welding. General recommendations are put forward to ensure satisfactory flash butt welding of non-alloy steels with < 0·4%C, either with or without preheating. Practical data charts are given.—M. D. J. B.

Specification for First Quality Spot Welding. (*Rivista Ital. Soldatura*, 1958, **10**, Aug., 154–155). [In Italian]. A brief description is given of the geometrical characteristics, permissible defects and the aspects of torsion tested fractures of high quality spot welds.

Points of View in Welding Cast Iron. C. Pfeiffer and S. Lundin. (*E.S.A.B. Svetsaren*, 1958, **23**, (2), 17–24). Various aspects of the structure of cast iron are discussed, with reference to Swedish cast iron standards, and the selection of suitable welding electrodes is dealt with.

Methods of Welding Circular Seams on Large Diameter Pipes. L. Hense and H. Scheruhn. (*Schweissen Schneiden*, 1958, **10**, May, 162–166). Hand welding and automatic welding of large diameter pipes for oil, water and gas are discussed and compared. The automatic method uses special electrodes and gives good mechanical properties in the weld area; it is less time-consuming than the hand method and does not require skilled personnel.

I.I.W. Commission III. Resistance Welding. Recommended Practices for Flash Welding. Part I: Plain Steels Containing less than 0·4% Carbon. (*Soud. Techn. Connexes*, 1958, **12**, March-April, 142–148). The paper describes the process in relation to the variables encountered. Procedures for welding with and without preheating are recommended. A diagram for calculating the length of material lost is given.—R. P.

Studies on Tests of Sensitivity to Welding Cracks with High-Strength Steel Plate. I. Comparison of Various Testing Methods. T. Saito. **II. Effect of Dimensions of Specimen on the Slit Welding Crack Sensitivity.** Y. Ito. **III. Consideration of the Application of the Slit Welding Crack Sensitivity Test.** Y. Araki. (*Tetsu to Hagane*, 1958, **44**, Mar., 372–374; 374–376; 377–379).—K. E. J.

Brazing Alloys for Guided Missiles. A. T. Cape. (*Met. Prog.*, 1958, **74**, Sept., 99–104). Many types of brazing alloys are now available and the selection of the right alloy depends on such factors as kind of materials to be joined, service to which it will be subjected and methods of brazing which are to be employed.—T. G.

Economical Gas Heat Treat Furnaces Effective for Close Carbon Control Work. D. E. Pullins. (*Western Metalw.*, 1958, Oct., 53–54). Some new gas-fired furnaces are described, including a humpback conveyor-type 47 ft long by 7 ft 6 in. high using dissociated ammonia or dry H_2 and having a temperature range of 1300 to 2050° F. This unit is used primarily for high-temperature brazing. The operation of a carbon control furnace is described. Lost carbon is replaced by maintaining close control over atmosphere and dewpoint. A number of other furnaces including some designed to use electricity, but converted to low cost gas heating are described.—R. S.

The Technique of Bonding Heavy Metal and Non-metallic Materials. H. Winter and H. Meckelburg. (*Schweissen Schneiden*, 1958, **10**, Nov., 423–433). A survey is presented of methods of bonding heavy metals one to another and to non-metallic materials. Bonding agents and surface pre-treatments are enumerated; experiments on steel bonding agents are reported; the bonding of steel to light metals; of copper, brass, and zinc; and of metal to wood are described.—L. J. L.

The Cutting of Ferrous and Non-Ferrous Metals. E. Sellier. (*Rev. Univers. Mines*, 1958, **14**, Oct., 359–372). The principles of oxygen cutting are discussed, with examples of the equipment used, followed by a review of powder techniques.

Powder Flame Cutting in the Construction of Chemical Apparatus. V. Trunschitz. (*Schweisstechn.*, 1958, **12**, Nov., 148–152). Flame cutting with the addition of Fe and other powders is described, and the structures obtained are discussed, with particular reference to stabilized and unstabilized 18/8 Cr–Ni steels.

The Scrapping of a 10-ton Cast Iron Jaw Crusher by Powder Flame Cutting. W. Lenk. (*Schweissen Schneiden*, 1958, **10**, Nov., 446–448). The principles of "powder flame cutting" are discussed; methods and equipment are described; the scrapping of a cast iron jaw crusher provides a practical example. The economics of the method are discussed

MACHINING AND MACHINABILITY

Faster Turning Solves Tough Stainless Problem. (*Steel*, 1958, **143**, Dec. 22, 67). An improved tool holder decreased tool cost in machining 17-4 PH stainless. A negative rake angle and a sulphur-base cutting oil are used.

New Investigations on the Relationship Between Chip Formation and Tool Life in the Machining of Steel with Cemented Carbides. G. Weber. (*Stahl Eisen*, 1958, **78**, Nov. 13, 1678–1690). The life of a tool tip, i.e. times between regrinding, was studied on a great number of steels ranging from mild to high-grade and is reported in detail with diagrams and tables. A formula was derived to characterize the technological behaviour of a steel taking into account the conditions of the cutting process. The wear of the tool tip

Investigation of Hot-dip Tinning Baths of

Protection of Steel and Other Materials (*Metall. Obra. Met.*, 1958, (9), 20–23). To

depends on the composition of the steel and therefore allows the classification of the steels with respect to tool wear. Wear is greater for plain carbon than for alloy steels, but type and manner of wear are different for the various steels. Chip build-up and effect of feed on wear are dealt with at length.—T. G.

Improvement of Machinability in Steels by Addition of Titanium Sulphide. T. Saito. (*Tetsu to Hagane*, 1958, **44**, Mar., 370–372).

Contribution to the Study of the Uses of Cutting Tools Made from Sintered Metal-Carbides. M. L. Broida. (*Met. Corr. Ind.*, 1958, Jan., **33**, 30–51; Feb., 71–84). After reviewing the development of cutting tools, the author discusses mechanical properties and methods of using steel and carbide tools. Methods of preparing tools and their behaviour and failures during use are dealt with. The author then discusses weight losses occurring during use of carbide tools, also abrasion; the relation between the work done in cutting and distance, temperature and rate of cutting are analysed, also the effect of variables on weight losses. (10 references).—R. P.

Tool Steel Failures. G. Davitz. (*Eng. Foundryman*, 1958, **24**, Aug., 63–70). The failures of tool steels are tracked down to neglect of the following five criteria: Sound steel of the proper grade; Correct heat-treatment; Good design; Proper grinding; and Proper application and operation.—T. G.

Working Speeds for Grinding Wheels. (*Aciers Fins. Spéc.*, 1958, Dec., 86–88). Tables are given and the relevant formulae.

The Influence of Various Factors on Metal Removal and Abrasive Consumption in the Grinding of Steel with Pendulum Grinding Machines. G. Wallquist, B. Hamrin and H. Lund. (*Jernkonts. Ann.*, 1958, **142**, (9), 541–569). A description of Swedish works trials to determine the effect of various factors on metal removal and abrasive consumption. Metal removal increases with pressure and peripheral speed, and consumption of abrasives increases with grinding pressure and metal removed. It is shown that the most effective way of reducing grinding costs is to use larger grinding motors with increased grinding pressure.

Determination of Fundamental Conditions in Peening. I. Relation between the Dent Size, Density and the Fatigue Strength. K. Kamishohara. (*Tetsu to Hagane*, 1958, **44**, Mar., 350–352). The best results for a 6 × 6 mm test-piece are given by peening to 100 dents of 0·16 mm dia. per mm² of surface; the fatigue limit is increased from 75 to 100 Kg/mm². Other results are given.—K. E. J.

Ten Tips to Better Scarfing. S. Shatuck. (*Iron Steel Eng.*, 1958, **35**, Nov., 131–132). Some practical hints on scarfing are given.

CLEANING AND PICKLING

The Preparation of Metals for Protective Finishes. R. E. Shaw. (*Met. Rev.*, 1958, **3**, (12), 327–356). A review of ferrous and non-ferrous metal treatments. (73 refs.).

Modern Chemical Processes for Degreasing and the Formation of Protective Layers on Iron and Steel. W. Rausch. (*Metalloberfläche*, 1958, **12**, Oct., 289–295). Modern methods of degreasing and phosphating are described, with some examples from practice.

Polishing of Stainless Steels. (*Aciers Fins Spéc.*, 1958, Dec., 74–76). A brief account of abrasive polishing and buffing.

Sand-Blasting and Pickling. H. Bablik and F. Gotzl. (*Mét. Constr. Mécan.*, 1958, **90**, Oct., 773–775). The importance of sand-blasting in preparing the surface for hot-dip galvanizing is emphasized, and the process is compared with pickling, in relation to its influence on the subsequent zinc coating.

Study on Acid Pickling. I. On the Interference of Ferrous Sulphate. R. Kawabata. (*Tetsu to Hagane*, 1958, **44**, Mar., 352–354). Detailed results are given for the effect of $FeSO_4$ (up to 7%) on corrosion loss (with and without inhibitor) of mild and high-carbon steel, roughness of mild-steel surfaces and pickling speed for mild steel.—E. E. J.

Pickling Agents and Pickling. F. Margival. (*Peint. Pig. Ver.*, 1958, **34**, Oct., 450–459). Degreasing apparatus (solvents and caustic) and pickling baths for ferrous and non-ferrous metals, inhibitors, plant and subsequent treatment are reviewed. (60 refs.).

Sulphuric Acid Regeneration Plant in the Acid Cycle of a Wire Pickling Shop. W. Mallach. (*Draht*, 1958, **9**, Sept., 335–342). The problem of acid recovery is analysed for the case of a wire mill with a pickling shop throughput of 12,300 tonnes/month on three-shift working. Batch pickling is envisaged for 8000 tonnes/month, continuous strand pickling for the balance. Complete design calculations are presented for the regeneration plant.—J. G. W.

The Regeneration of Electrolytes for the Electrolytic Polishing of Carbon Steel. T. Zak. (*Metalloberfläche*, 1958, **12**, 361–363). The extent to which impurities such as Fe^{2+} and Cr^{3+} are deleterious to electrolytic polishing baths containing chromic acid is examined, and methods of removing these constituents are described.—L. D. H.

Treatment of Residual Liquors from Metal Treatment. G. Allais. (*Corros. Anticorros.*, 1958, **6**, July-Aug., 252–257). The treatment and disposal of contaminated water from the industrial treatment of metals is discussed.

PROTECTIVE COATINGS

Research on Microthrowing Power and Leveling of Plating Baths. E. Raub. (*Plating*, 1958, **45**, May, 486–492). Structures and mechanism are considered. The experiments were made with Ni or Cu on brass.

Modern Surface Treatment. K. Jahnsen. (*Jerndustri*, 1958, **39**, Oct., 208–214, 223). Quality control of surface treatments is discussed, including phosphating, lacquering and electrolytic polishing.

Porosity of Films. W. Bratkowski. (*Ind. Eng. Chem.*, 1958, 50, Dec., 73A–74A). Tests for pinholes in plated coatings are briefly reviewed.

Studies on the Electrodeposited Chromium Film. I. N. Awa and O. Fusida. (*Nippon Kinzoku*, 1957, **21**, July, 447–449). Uniformity of plate thickness may be improved by surrounding the cathode by a frame. The best is selected from four designs, and a further improvement follows from reducing the area of contact between cathode and frame. A variation from 5μ at the centre to 4μ at the periphery of the cathode is obtained. The method can be used for gauge blocks.—K. E. J.

Nickel Plating and Its Industrial Application. H. C. Castell. (*Mét. Corros. Ind.*, 1958, **33**, Sept., 366–376). Various techniques are outlined for the electrolytic deposition of nickel, and for the non-electrolytic deposition of Ni–P alloys.

Industrialisation of Chemical Nickel Plating. R. Bailleul. (*Corros. Anticorros.*, 1958, **6**, Feb., 48–50). The principles of nickel coating by chemical methods are summarized and the properties of these coatings are discussed. They consist of 92%Ni and 8%P, melting at 890° C. Their hardness depends on structure and temperature. Thermal shock causes cracks. Ni coatings may be used for corrosion prevention, welding, brazing, prevention of contamination by iron and its oxides and for covering plastics. Materials which may be covered by nickel include iron, steels, Al, Cu, and its alloys, ceramics, glass and Ti.—R. P.

Electroplating. Bright Plating of Nickel. E. Bertorelle, T. Bellobono and C. Bordonali. (*Galvano*, 1957, **26**, Nov., 29–32; Dec., 28, 33). The authors summarize developments made in the bright-plating of nickel over the last 25 years. They go on to discuss the five main theories for obtaining a bright nickel deposit and then expound their own theory based on research work. The authors state the experimental details of their tests and give results obtained under 47 different conditions. (35 references).—R. P.

Alkaline Nickel Plating. E. B. Saubestre. (*Plating*, 1958, **45**, May, 479–485). A review with bath compositions and discussion.

On Chemical Nickel Plating. L. A. Rubio Felipe. (*Inst. Hierro Acero*, 1958, **11**, July-Sept., 202–210). [In Spanish]. A study of the factors affecting the process in acid and alkaline baths is reported. It is concluded that: (i) for a maximum velocity of reduction of the nickel ion it is necessary that the relationship between the true concentration of the nickel and hypophosphite should have a fixed value; (ii) the pH must be controlled since the reducing power of the hypophosphite depends on this and, if high, basic nickel salts will precipitate with the metal; (iii) sodium acetate will stabilize the pH in any acid bath; (iv) it is necessary to stabilize the solution with a complexing agent; (v) sodium benzenedisulphonate additions result in very bright deposits and improve the levelling action of the bath; (bi) Al can be plated if it is inclusion-free and the plating is slow, and; (vii) the effect of the organic acids studied on the hypophosphite reducing power could not be assessed.—P. S.

The Galvanizing Association and the Society for "Zinc and its Alloys." C. A. Wahl. (*Galvano*, 1958, **27**, May, 39–42). An address given to Conference held in February, 1958. The speaker discusses the use of zinc as a corrosion protector and then summarizes the functions of the Society for zinc and its Alloys. The uses of "Kayem" alloys of zinc for tools, injectors and presses are summarized.—R. P.

Hot-Dip Galvanizing Practice. A. T. Baldwin and W. H. McMullen. (*Galvano*, 1957, **26**, Nov., 36–43; Dec., 29–33). The authors give a brief review of developments in hot-dip galvanizing over the last 25 years. Pickling and pickling solutions, galvanizing baths and attack on these by the molten metal and methods of handling are discussed. The authors then discuss continuous processes for the galvanizing of wire, sheet and strip. The structure of the zinc coating and the influence of aluminium are commented on.—R. P.

Hot-Dip Galvanizing of Cast Iron. M. H. Davies. (*Foundry Trade J.*, 1958, **105**, Dec. 4, 685–687). The method is outlined and the surface conditions for satisfactory coating and design and methods of attaining these are briefly discussed.

Distribution and Action of Aluminium in a Galvanizing Bath. R. Haarmann and D. Horstmann. (**Stahl Eisen*, 1958, **78**, Dec. 11, 1808–1811). Concentration gradients of Al in galvanizing baths exist only for a very short time after the Al addition, the Al distribution in the zinc bath is normally even. With increasing Al content of the bath the thickness of the zinc layer decreases, but increases for Al contents above 0·2%. The uniformity of the zinc layer reaches its maximum for Al contents of about 0·2%, at higher Al proportions a variety of defects of the zinc layer is observed. Adherence of the zinc increases with increasing Al content, this being attributed to the inhibition of the formation of a iron–zinc alloy layer by Al.—T. G.

Modern Wire Galvanizing Plants. F. Rüb. (*Draht*, 1958, **9**, May, 170–174). Among the recent developments described in this review are coiling and uncoiling equipment for both hot-dip and electro-galvanizing, electrical heating of galvanizing baths by means of a lead bath, and single-strand electro-galvanizing installations.—J. G. W.

The Attack of Zinc Melts Saturated with Iron on Titanium-Bearing Iron. D. Horstmann. (*Arch. Eisenh.*, 1958, **29**, Dec., 731–735). The attack of iron-saturated Zn melts on Fe is increased by Ti in the Fe. The laws governing this reaction are examined for various temperature ranges.

Occurrence of a Ternary Carbide in the Attack of Liquid Zinc on Iron–Carbon Alloys. L. J. Hütter and H. H. Stadelmaier. (*Z. Metallk.*, 1958, **49**, Nov., 600–601). It is shown that a ternary carbide Fe_3ZnC is formed on the Fe surface in the reaction between Fe, C and molten Zn. This carbide, embedded in the δ_1, has an ordered face-centred cubic lattice with a constant of 3·80kX.

Methods of Testing Zinc Coatings on Steel Screws. H. G. Bobe. (*Draht*, 1958, **9**, June, 218–219). Two testing procedures not included in German Standards are described and commented on, namely a "drop etching" test and a copper sulphate dip test.—J. G. W.

Investigation of Hot-dip Tinning Baths of Various Compositions, Notably with a High Lead Content, With or Without Salt Cover. (*Draht*, 1958, **9**, Aug., 304–306). Investigations of the hot-dip tinning of wire are reported, the purpose of which was to ascertain the most suitable mixture of salts for covering the bath so as to prevent slag formation. The investigation was not successful.—J. G. W.

Aluminium-Coated Iron Castings. (*Usine Nouv.*, 1959, **15**, Jan. 22, 98–99). Electrolytic Al deposition from a fused salt bath is described as carried out in the U.S. The metal can also be pickled and dipped in molten Al. Methods of testing and control and the structure produced are outlined and the corrosion and heat resistance is compared with that of galvanized iron.

Titanium Coating. I. Titanium Coating by So-called Pyrosol. Y. Ogawa, Y. Hisamatsu and K. Kawamura. **II. Titanium Coating by Fused-Salt Electrolysis.** Y. Ogawa, Y. Hisamatsu, K. Kawamura and J. Tatsuma. (*Nippon Kinzoku*, 1957, **21**, Oct., 597–599; 599–602). I. Titanium can be deposited on a steel sheet when it is immersed side by side with titanium sheet or powder in a fused bath of NaCl, KCl or a mixture. The coating thickness depends mainly on temp. and time. The micro-Vickers hardness is 400–600, and a high resistance to corrosion is obtained. II. A coating can be produced by electrolysing TiF_4 dissolved in KCl–NaCl mixture under an argon atmosphere. Optimum conditions include using a modulated direct current. The micro-Vickers hardness is approx. 300, but the corrosion resistance is the same as with the "Pyrosol" method.—K. E. J.

Contraction Stresses in Sprayed Metal Deposits. W. E. Stanton. (*Met. Ind.*, 1958, **93**, Dec. 19, 509–511). Mild steel sheets thinly coated on one side with Mo were sprayed with Zn, Cu, Al, bronze, 0·9%C steel, 13%Cr steel, Ni,Cr/Mo steel, 0·7%C steel, 0·4%C steel, Swedish iron and 18/8 stainless. The amount of bending produced was observed and related to sprayed metal composition and thickness. The structure of the sprayed metals and possible phase changes taking place are discussed.

The Protection of Sections by Metallisation. (*Prat. Soud.*, 1958, **12**, Feb., 29–32). A description of sand-blasting and metallization with Pb of sections for rail catenary supports.

Phosphate-Coating with Iron Phosphate. M. J. Demesse. (*Corros. Anticorros.*, 1958, **6**, Feb., 37–39). The author gives a brief review of the history of phosphate coating and compares the various methods. He points out advantages of ferrous phosphate over those of Mn or Zn. The ferrous phosphate solution remains reduced; pickling and washing are not necessary. Only one bath is required after degreasing.—R. P.

Variations in Density and Protecting Power of Phosphate Coatings on Iron According to the Time Taken for Their Deposition. E. Jimeno and A. Arévalo. (*Corros. Antocorros.*, 1958, **6**, Feb., 51–58). The authors describe experiments to show that the density of phosphate coatings is not a direct function of the time taken to produce these layers. Partial dissolution of the crystalline layer takes place and it recrystallizes. This is accompanied by modification of the grain size. Corrosion prevention is more efficient the denser the coating. (10 references).—R. P.

Phosphating Techniques. Recent Improvements. R. Lagarde. (*Corros. Anticorros.*, 1958, **6**, March, 107–108). The author gives a brief review of phosphating methods and the various phosphates used. Recent improvements are due to the use of polyphosphates such as pyrophosphate, hexametaphosphate or tripolyphosphate in concentrations of 0·1 to 0·5 g/l. Organic complexes (chiefly derivatives of ethylenediamine) help to develop a thicker coating and keep the bath clear.—R. P.

Asphalt-Type Protective Coatings for Underground Pipe Lines. NACE Technical Unit Committee T-2H. (*Corrosion*, 1958, **14**, Aug., 373t–374t). Tentative specifications are given for asphalt wrapped systems of primer, enamel, wrapping and test methods.

Protection of Steel and Other Materials by Means of Hard and Soft Rubber. H. Ziegner. (*Draht*, 1958, **9**, Sept., 344–346). Rubberizing techniques are described and the resistance to chemical attack by numerous substances is tabulated for the two types of rubber.—J. G. W.

Surface Treatment of Mass-Produced Articles in Steel. K. Jahnsen. (*Jernindustri*, 1958, **39**, Nov., 227–231, 242–243). Surface treatments of mass-produced steel articles, including lacquering, are discussed.

Effect of Accompanying Elements on the Enamelability of Steel Sheets. W. Tepohl. (*Stahl Eisen*, 1958, **78**, Nov. 27, 1765–1768). A review of published information on the effect of the elements present in steel on its behaviour during enamelling dealing with C, O, H, N, P, S, Mn, Al, Cu, Ni, Co, Cr, Mo, V, and Ti.—T. G.

Factors in the Fabrication of (Grey) Iron Castings Which Can Cause Defects in Vitreous Enamelling. A. Bordes. (*Metalen*, 1958, **13**, Nov. 29, 396–401). Metallurgical problems connected with the manufacture of grey iron castings to be treated by vitreous enamelling are outlined; the article deals with factors, applying to various stages of manufacture, which can influence the quality of the enamel.

Coatings for Underwater Metal Surfaces in Fresh Water Exposures. S. M. Gleser. (*Corrosion*, 1958, **14**, Aug., 377t–386t). Lock and dam components along the upper Mississippi were examined. Tests on > 190 panels over 18 years were made with various painting systems.

Influence of the Surface State of Steel on the Protection Provided by Paints of High Zinc Content. G. Binetti and G. Ghisolfi. (*Corros. et Anticorros.*, 1958, **6**, Oct., 352–362). From a study of the electrochemical protection provided by zinc-rich paints and tests under service conditions, conclusions are drawn about the suitable preparation of the steel for painting.—A. G.

CLAD SHEET AND HARD-FACING

The "Spray Fuse" Hard Facing Process for Stellite Cobalt Base Powders. S. R. Gault and D. A. Ironside. (*Machinery*, 1959, **94**, Jan. 28, 189–197). The development of Co-base Stellite and its use for coating pump shafts and sleeves, pyrometer sheaths and other parts are described. The new process gives thinner deposits than do the oxy-acetylene and arc processes. Standard powder-spraying pistols are used, and structures are shown. The cold-sprayed deposit is fused with an oxy-acetylene torch after deposition.

Characteristics of New Methods of Pistol Spraying of Ceramic Powders or Hard Alloy Metallics. M. Muller. (*Prat. Soud.*, 1958, **12**, Apr., 73–76). An outline is given of the materials used and the techniques employed in metallization by means of a variety of alloy powders, and the application of coatings of ceramics and cermets.

POWDER METALLURGY

What Carbon and Alloys do for Iron Powder. S. R. Crooks. (*Met. Prog.*, 1958, **74**, Dec., 68–73). Improved mechanical properties, particularly strength, of powder-metallurgical parts were obtained when the iron powder was alloyed with 1% graphite and 1% lubricant (zinc stearate) or with 2%Ni, 0·5%Mo and 0·3%Mn.—T. G.

Continuous Sintering of Quality Powdered Metal Parts in a Mechanized Furnace. (*Ind. Heat.*, 1958, **25**, Oct., 1964–1968). A description is given of a new pusher type gas-fired sintering furnace with a preheat and high heat zone, operating on a continuous basis.

The Hot Strength of Sintered Metallurgical Substances. I. N. Franzewitsch. (*Neue Hütte*, 1958, **3**, Dec., 732–739). The physical and chemical properties which are of importance in the use of sintered metals and ceramics at high temperatures are examined theoretically and in the light of typical examples.

On Some Properties of Iron–Copper Alloys Obtained by the Method of Impregnation. I. N. Frantsevich and O. K. Teodorovich. (*Metall. Obra. Met.*, 1958, (9), 20–23). To avoid etching or loosening of the boundaries the specimens were made from solutions of Cu in Fe and Fe in Cu mutually in equilibrium at the sintering temperature and ageing of both phases was thus facilitated. The sintering was carried out in H_2 at 1050° C for 20 h for the iron (+ 8%Cu) and the Cu (+ 5%Fe) was melted in H_2. The specimens were impregnated in H_2 at 1120° for 30 min and pore-free specimens were examined. Hardness and other measurements were made.

The Influence of Small Amounts of Solid Solution-Forming Alloy Constituents on Sintering Behaviour. F. Thümmler. (*Planseeber.*, 1958, **6**, April, 2–16). The influence of small amounts of solid solution-forming alloying elements on the sintering behaviour of Fe, Co, Cu and Ag was tested. If the solid solution is formed first, sintering is not improved, the sintering of Fe–Sn and Fe–Mo being hindered. Sintering behaviour in relation to size factor and mechanical properties is discussed. If the solid solution is formed *in situ*, the sintering behaviour of the systems investigated is improved. (22 references).—R. P.

FERRITES, CERMETS, AND CARBIDES

Sintered Ceramic Tool Materials. I, II. M. J. C. Matthijsen. (**Metaalbewerking*, 1958, (22), 452–457; (23), 467–470). A discussion of hard materials and the development of cermets with special reference to the alumina compositions and their physical and mechanical properties. Turning tests are used to assess the effects of porosity and hardness and elasticity are also considered as well as method of production and the theory of sintering. Recommendations as to purity, grain size and compacting and sintering methods and the effects of additives on grain growth are made.

On the Preparation and Properties of Sodium Ferrites. J. Théry and R. Collongues. (*Compt. Rend.*, 1958, 247, Dec. 1, 2003–2006). Three ferrites were recognized by X-ray methods. Only the orthorhombic Na_2O, Fe_2O_3 is stable, but a rhombohedral form and $2Na_2O$, $3Fe_2O_3$ also occur.

Preparation of Magnetic Ferrites. (I), Ferrite Formation of Precipitates from Mixed Solutions of Bivalent Metallic and Ferric Ions. J. Tasaki, T. Izushi and K. Kajima. (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1958, **7**, Nov., 833–846).

Faraday Rotation and Loss Characteristics of Ni–Mg, Mg–Mn and Ni–Zn Ferrites in 3 cm Wave-Length Region. Huang Wu-han, Ling Jan-dah and Ho Chang-sheng. (*Acta Phys. Sinica*, 1958, **14**, Nov., 431–441).

PROPERTIES AND TESTS

Some Effects of Chemical Composition on the Mechanical Properties of Steels. G. Mayer and L. H. Toft. (*Rev. Nickel*, 1958, **24**, (2), 27–38). The influence of chemical composition on the tensile and impact strength of various steels is examined in detail. The effects of certain metallic additions are greater with a bainitic than with a martensitic structure.

Crystal Structure and Deformation. E. Schmid. (*Metall.*, 1959, **13**, Jan., 1–11). The relation between crystal structure and deformation is examined for crystals of several metals, with some reference to Fe. (82 refs.).

Beam and Column Tests of Welded Steel Tubing with Design Recommendations. D. S. Wolford and M. J. Rebholz. (*A.S.T.M. Bull.*, 1958, Oct., 45–51).

The Mechanical Properties of An Experimental Silicon–Nickel Steel Containing 0·3% Carbon. A. S. Kenneford. (*TIDU* 6013, List 971, pp. 17). Effects of tempering up to 700° C on mechanical properties are given and it is shown that the 2%Ni has no advantages over Mo in a 2%Si steel.

The Autumn Metallurgical Conference. (*Met. Constr. Mec.*, 1958, **90**, Nov., 819–837). A summary of papers presented at the above conference of the Société Française de Métallurgie. **Mechanism of Intergranular Fragility**

of Al–Zn and Al–Zn–Mg Alloys: Effect of Polygonisation on Fragility. P. Gobin and J. Montuelle. **Report on the Phenomena of Intergranular Adsorption and a Study of Their Relations with Intergranular Fragility.** G. Henry, J. Plateau, X. Waché and M. Gerber. **Contribution to the Study of the Mechanism of the Brittle Rupture of Mild Steel.** J. B. Leun, J. Plateau and C. Crussard. **On the Relation between the Distance of an Inclusion from the Surface and the Influence of the Inclusion on Fatigue Cracking.** H. de Leiris and E. Frappier. **Effect of Inclusions on the Formation of a Fracture and the Mechanical Properties of Steel Castings.** M. Matuschka. **Some Features of the Process of Fracture of Alloys at High Temperatures.** V. Serensen. **Brittle Fracture of Ductile Metals in Relation to State of Constraint.** G. V. Ugik. **Propagation of Cracks Initiated by Fatigue at Low Temperatures.** M. Weisz, R. Tamhankar, J. Plateau, G. Henry and C. Crussard. **Effects of Oligo-Elements: Systematic Analysis Using Irradiation of a Large Numbers of Impurities in Aluminium and in Very Pure Iron Made by Zone Melting.** P. Albert and J. Gaittet. **The Effects of Very Small Quantities of Elements on the Resilience of Medium-Alloy Steels Quenched and Tempered.** J. M. Capus. **The Brittleness of Special Steels as Cast. Influence of Impurities and of Structure.** A. Gueussier and R. Castro. **Experimental Study of Solidification Cracks in Steels: Effects of Impurities.** R. Castro and A. Gueussier. **Influence of Some Elements in Traces on the Strain in Brittle Fracture in Iron and Iron Alloys of High Purity.** B. E. Hopkins and H. R. Tipler. **The Effect of Several Elements on the Stability of Stellite.** K. Lobl, J. Jezek and H. Tuma. **Addition of Bismuth to Some Cast Irons.** J. C. Margeric and M. Drouzy. **A Study of the Effects of Residual Elements on the Tensile Strength of Wire Rod.** B. Matuschka. **The Effect of Small Contents of Tin on the Mechanical Properties of Cold-Rolled Sheets.** P. Rocquet, G. Jegaden and R. Tarriant. **The Effects of Small Quantities of Arsenic, Tin, Antimony and Lead on the Metallographic Structure of Cast Grey Iron.** A. Scortecci, R. Sacerdote and E. Stagno. **Some Characteristics of Interstitial Solid Solutions: Behaviour of Boron in Iron.** J. W. Spretnak and R. Speiser. **A Study of the Thermal Evolution and Physical Chemistry of the Basic Bessemer Conversion Process for Recording Bath Temperature.** J. Galey, L. Beaujard, P. Vallet and G. Urbain. **The Basic Bessemer Process.** J. Marot and I. Harveng. **The Relation between the α-Phase in Cold Working and the Parent Austenite in Low-Carbon 18–8 Steels.** P. Bastien and R. Margerand. **Blowing Powdered Products in the Converter Blast.** B. Trentini, P. Vayssière, R. Alleyrac and J. Legrandjacques. **Refining Pig Iron with Pure Oxygen and Lime Powder. The IRSID–OLP Process.** B. Trentini and M. Allard.

Roughness of Worked Surfaces and Its Measurement. I. U. Krause. (*Stahl Eisen*, 1958, **78**, Dec. 11, 1827–1832). A review of the principles of roughness measurement of worked surfaces is given, the various methods in current use described and the reproduction and consistency of the test results discussed.—T. G.

Improvement of the Quality of the Surface Layer of a Metal by Electromechanical Smoothing. B. M. Askinazi. (*Metall. Obra. Met.*, 1958, (9), 49–53). In this process a high intensity low-voltage current passes between tool and workpiece. Steel 40Kh, quenched or normalized, was used and surface hardness was measured and microstructure compared with a mechanically ground surface. Wear tests were also made. The electromechanical process shows advantages.

Metals. [Ferrous and Non-ferrous, and Fatigue]. (*A.S.T.M.S.T.P., No.* 196, 1957, pp. 175). **Studies on Type 301 Stainless Steel Columns.** J. Dubuc, V. N. Krivobok, and G. Welter. (1–21). Tests in compression are described. Buckling related to slenderness ratio was in general agreement with the theory of Watter and Lincoln. Effects of creep or cycling the applied load, and stress-relieving and relatively low temperature heat treatment are discussed. **Shotpeening Effects and Specifications.** H. O. Fuchs. (22–32). A method of obtaining equivalent intensities is included. **Effect of Forming on Mechanical Properties.** J. L. Waisman and C. S. Yen. (33–44). Effects of bending and stretching on 302 stainless and non-ferrous alloys are reported, explanations and methods of prediction are advanced. **Axial Stress, Fatigue, Creep, and Rupture Properties of Unnotched and Notched Specimens of Heat-Resistant Alloys.** F. H. Vitovec and B. J. Lazan. (45–62). Stainless Type 403 and other alloys were tested. **Determination of Young's Modulus under Conditions of Relaxation.** R. W. Fenn jun. (63–76). Apparatus is described with special reference to methods of gripping the specimens and degrees of misalignment and their effects on values obtained. **Effect of a Number of Variables on the Fatigue Properties of High-Strength Steels.** G. Sachs, B. B. Muvdi, and E. P. Klier. (77–93). Steels of aircraft quality machined from 3 to 4½ in. round or square sections, heat-treated to strength values between 210 000–290 000 psi, were tested and the effects of specimen position in the section, as-processed section, strength level or tempering temperature, stress concentration, and fibre structure or directionability are evaluated. **Uni-Directional Axial Tension Fatigue Tests of Beryllium Copper and Several Precipitation-Hardening Corrosion-Resistant Steels.** M. H. Weisman, J. Melill, and T. Matsuda. (123–142). Notched tensile and smooth and V-notch fatigue tests are reported. AM350, A–286, and 17–7PH steels were used. Single-lap riveted aircraft joints in AM350 were also simulated and 17–7PH specimens with unloaded rivet-filled holes were included. The kind of information needed for design purposes is considered.

Relationship between the Mechanical Properties in the Casting and in the Separately Cast Test Bar. W. Patterson and F. Iske. (*Giesserei Tech. Wiss.*, 1958, Sept., 1147–1169). Assuming that a logarithmic relationship exists between solidification time or time of transformation and the surface/volume ratio of a casting, the mechanical properties of test pieces and castings were investigated, for cases where the surface area/volume ratio was exactly defined. Equations for tensile strength and hardness were derived, from which nomograms were constructed to give direct readings of these quantities could be made from a knowledge of the surface/volume ratio and the chemical composition of casting and test bar. (29 refs.).

Proceedings of the 1955 Sagamore Research Conference. Strength Limitations of Metals. I. (*U.S. Dept. Commerce, PB* 131280, 1956, Mar., pp. 203). **Introduction.** A. P. Taber. (4–7). **Requirements for Strength Increases in Ordnance.** N. L. Reed. (8–10). **Summary of Strength Limitation Phenomena.** G. Sachs. (11–35). Tests and their interpretation are summarized and the effects of alloying elements, hydrogen, and heat and mechanical treatments are referred to. (25 refs.). **Dislocations and Strength.** P. B. Hirsch. (36–70). A fully illustrated discussion. (19 refs. and tables). **Effects of Grain Size, Solid Solution and Other Metallurgical Factors on Strength.** E. R. Parker. (71–83). Dislocation theory is outlined. **Effects of Transformations and Precipitations on Strength.** E. P. Klier. (84–102). The maximum strength that can be developed in constructional materials is discussed, mainly with reference to heat treatment. **Dependence of Strength on Loading Speed and Loading Time.** D. S. Wood. (103–124). Both conventional loading and wave propagation phenomena are considered. **Strength Limitations under Repeated Load.** E. D'Appolonia. (125–142). Fatigue testing is described and results for a Ti alloy are given. **Effect of Section Size on Fracturing.** J. D. Lubahn. (143–161). The process of fracture and the experimental findings are clarified but no mechanisms are considered. **Effects of Stress Concentrations, Fibering, and Residual Stresses.** O. Hoffman. (162–178). Large forgings, especially for aircraft landing gear, are considered. **Effects of Hydrogen on High-Strength Alloys.** V. Weiss. (179–196). Steels and Ti alloys are particularly discussed. **Discussion of Hydrogen Embrittlement.** N. E. Promisel. (197–203). Trials on eliminating the effect from steel are reported, with a note on the effect of corrosion. **II.** (*PB* 131281, pp. 204–402). **Super-High Strength Steels for Aircraft Applications.** J. W. Sands. (204–232). Data on 13 steels are given, four in use in 1955 and nine under trial. **High Impact Strength Steels for Low Temperature Service.** A. Hurlich. (233–257). Gun tubes and armour are mostly discussed. Effects of rare earth metals are shown. **Strength Limitations of High Strength Steels at Moderately Elevated Temperatures.** W. F. Brown jun. (258–288). Creep and impact properties up to 800° are shown and heat treatments discussed. **Onset of Fast Crack Propagation in High Strength Steel and Aluminium Alloys.** G. R. Irwin. (289–305). A force tendency concept is used and work on SAE 4340 steel is reported. Fractures are illustrated.

Determination of Tensile, Compressive, Bearing, and Shear Properties of Ferrous and Non-Ferrous Structural Sheet Metals at Elevated Temperatures. J. V. Melonas and J. R. Kattus. (*WADC Tech. Report* 56–340; *ASTIA Document AD* 131069; *PB* 131461–650, 1957, Sept., pp. 282). AISI–4130 alloy steel at nominal strength levels of 150 000, 180 000 and 200 000 psi and a Type 301 full-hard stainless were used. The apparatus is shown and numerous curves and tables display the results. D. E. Miller. (*AF Techn. Report No.* 6517, **V**; *ASTIA Document AD* 142218; *PB* 131595 250, 1957, Dec., pp. 90). Type 301 half-hard and Type 302 annealed stainless, and also an SAE 4130 alloy steel were included, and tested at 400°, 600°, 800°, and 1 000° F after ageing at test temperature for 30 min. The samples were from sheets that had been in storage for 3–5 years and this long-term ageing had apparently some effect. Fully annealed materials were not affected by storage. Methods and results are described.

Testing of the Mechanical Properties of Constructional Steel. K. Onaran. (*Bull. Tech. Univ. Istanbul*, 1958, **11**, (1), 29–44). [In English]. Products manufactured at Karabuk were examined. Tensile, bend, torsion, shear, creep, hardness, wear, impact, and fatigue tests were made on bars, nails, profiles, and sheets. (14 refs.).

Some Observations on the Portevin-Le Chatelier Phenomenon. R. Tamhankar. (*Tisco*, 1958, **5**, April, 53–65). The author reports the results of studies on Armco iron and nickel–chromium (35/10) austenitic steel, and shows that there is a definite temperature range (depending on strain rate and grain size) for the occurrence of the mechanical instabilities causing serrations in tensile curves. It is also shown that serrations in the case of Armco iron can be explained by interactions between impurity atoms like carbon, nitrogen, and oxygen, and by dislocations. For the austenitic steel, the author suggests that the instabilities are probably caused by interaction of partial dislocations generated by stacking faults with substitutional atoms like nickel. (25 references).—L. E. W.

A Survey of the Structural Properties of Some High Strength Sheet Steels. M. A. Melcon. (*N.A.T.O. Advisory Group for Aeronautical Research and Development*, Report 101, 1957, April, pp. 25). Heat-treatable stainless steels 420, 422, 422M, AM350, 17–7PH, Tri-cent, and Thermold J are considered, with comparisons with Ti and Al. Stress–strain curves in tension and compression at room and elevated temperatures, heat-treatment, corrosion-resistance, and formability are discussed, also fatigue, creep, stress-rupture and tear strength data, and some notes on welding, machining, and distortion during heat-treatment are added.

Tensile and Creep Properties of Tungsten at Elevated Temperatures. J. W. Pugh. (*Proc. A.S.T.M.*, 1957, **57**, 906–916).

The Static Properties of Several High-Strength Steels. E. P. Klier, B. B. Muvdi and G. Sachs. (*Proc. A.S.T.M.*, 1957, **57**, 715–730). SAE 4340, V-modified 4330, 98B40, and proprietary Hy-Tuf, Crucible UHS–280, Super

TM–2, and Tricent steels were used to ascertain the effects of strength level, orientation, composition, load eccentricity, as-processed section size, and stress concentration on notched tensile properties.

The Effect of Vibrations on the Static Yield Strength of a Low-Carbon Steel. G. E. Nevill jun. and F. R. Brotzen. (*Proc. A.S.T.M.*, 1957, **57**, 751–758). In the range 15–80 kc, applied vibrations reduce steady stress yield in tension and the reduction is proportional to amplitude but independent of frequency, temperature, and pre-strain. A mechanism is suggested.

On the Variance of the Bending Strength of Quenched Steel Wire. M. Tagaya and Y. Soyama. (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1958, **8**, March, 125–129). The observed variability appeared to contain a factor other than conditions of quenching and testing.

Experiments on Bending Changes with Surface Tests on Alpha-Iron Single Crystals for the Determination of Resistance to Change and Slip-Bands. F. Wever, A. Kochendorfer, M. Hempel, and E. Hillenhagen. (*Forsch Wirts. Nordrhein-Westfalen*, 1957, No. 410, pp. 100). Phase-contrast and other studies of strained, annealed single crystals containing 0·006% C to reveal the slip bands are reported.

The Expenditure of Force and Work as Well as the Energy of Bending of Steel Reinforcement in Relation to Measurement, Shape, and Quality of Steels. (Study of Principles of Power). G. Garbotz. (*Forsch. Wirts. Nordrhein-Westfalen*, No. 99, 1955, pp. 122). The apparatus used is described and numerous values are given and correlations of change of shape with the stress–strain diagrams are investigated.

Mechanical Behaviour of Microcrystals. W. W. Webb and W. D. Forgeng. (*Acta Met.*, 1958, **6**, July, 462–469). Small crystals (whiskers) of several materials, including Fe_3C, were extracted chemically from 2-phase alloys, and bend tests were carried out. Fe_3C was isolated from 1·3% C steel, it appeared at the boundaries of large primary austenite grains and as ribbons of cementite projecting from the original boundaries through a mixture of fine pearlite. The extracted carbides consisted of platelets and ribbons from 1–3μ thick and up to 1 mm long. The crystals showed high strengths, approaching theoretical values for perfect crystals, suggesting that small crystals may generally possess high strengths. There is some evidence that the presence of dislocations may have little or no effect on the mechanical properties of hard or brittle microcrystals, either when isolated or while dispersed in an alloy. (27 refs.).

Melting of Very Pure Iron after the Carbon Reduction Process and the Notch-Toughness–Temperature Curves for this Iron. A. Fischer, H. Treppschuh and K. H. Köthemann. (*Forsch. Wirts. Nordrhein-Westfalen*, 1957, No. 455, pp. 25). The iron was reduced in a vacuum of 10^{-2}–10^{-4} mm. Oxide inclusions and coercivity measurements were also studied.

A Laminated Specimen for Charpy Impact Testing of Sheet Metal. S. V. Arnold. (*Proc. A.S.T.M.*, 1957, **57**, 1 273–1 281). Blanks are cut from the sheet and riveted together and the specimen is machined from the laminate. The data are reproducible and sensitive to variables affecting toughness. Steel plate and Ti alloy were used.

Shock-Wave Compressions of Twenty-seven Metals. Equations of State of Metals. J. M. Walsh, M. H. Rice, R. G. McQueen, and F. L. Yarger. (*Phys. Rev.*, 1957, **108**, Oct. 15, 196–216). Iron is included.

Comparison of Charpy V, Charpy U, and Izod Notched Bar Tests over Transition Temperature Range. A. W. Johnston. (*Metallurgia*, 1958, **58**, Sept., 129). Investigations to compare the results of these three types of test were made on three mild steels and three alloy steels. No simple relationship was found to apply to all of the steels; the relationship between Izod and U-Charpy results proposed in B.S. 131: 1933 applied only to the alloy steels, a similar but different relationship holding for the mild steels. Other results are summarized.

Twinning in Explosively Loaded Steel. Sampooran Singh and A. Soundraraj. (*J. Appl. Phys.*, 1958, **29**, Jan., 111–112). Cylinders were machined from 0·37% C, 0·76% Mn, 0·25% Si steel and loaded with explosive and fired. Twinning is shown.

Testing Unalloyed Steels in the Multiaxially Stressed Condition by Means of Internal Pressure Experiments. W. Kuntze and A. Krisch. (*Arch. Eisenh.*, 1958, **29**, Sept., 599–602).

Internal Pressure Tests at Low Temperatures on Tubular Specimens. A. Krisch. (*Rev. Mét.*, 1958, **55**, June, 555–561). The experimental conditions and results are described of tests at temperatures from + 20 to − 70° C carried out under internal pressure combined with longitudinal stress, on tubular specimens of two killed basic Bessemer steels. The steels were tested in the annealed and artificially aged conditions, and their mechanical properties and the appearance of the fracture are discussed.

Factors Influencing the Behaviour of Some Types of Austenitic and Ferritic Steel During Hot Plastic Deformation. E. Terlecki. (*Hutnik*, 1957, **24**, June, 222–227). [In Polish]. Different types of fracture, occurring during hot plastic deformation of stainless steel, their causes and methods for their prevention are discussed.

On the Changes in Distribution of Hardness and Structure Caused by Cold Working of Metals and Some Phenomena Related to Them. (I). On the Distribution of Hardness and Structure Caused by Cold Drawing and Some Considerations on the Phenomena. I, II. W. Ota. (*Nippon Kinzoku*, 1956, **20**, July, 360–363; 363–367). Hardnesses were measured on transverse and oblique sections of Armco iron and nickel. The distribution showed distinct differences between the surface, intermediate, and centre parts. Relationships between the change in hardness and the reduction at one pass and between hardness distribution and internal stress are investigated. (19 references). The microscopical structures caused by cold-drawing fall into the same three groups. The processes of hardening by drawing, and the effect of cold-drawing and subsequent annealing on mechanical properties are discussed. **III. On the Distribution of Hardness and Structure Caused by Cold-Rolling. 1, 2.** (Aug., 417–421; 421–424). (1) For Armco iron and Ni, results are given for hardness distribution in transverse and oblique sections for various degrees of working, the effect of skin pass on hardness distribution, and the relationship between hardness and residual stress. (2) For a cold-rolled plate, the relationship between hardness distribution and the occurrence of cracks at the edge was studied. The surface structure is discussed. The effects of rolling through a groove on hardness and structure, and of cold-rolling and annealing on mechanical properties, are studied. **V. The Effect of External Stress Upon the Distribution of Hardness and Structure and Magnetic Properties. VI. [Characteristics] of the Tensile Fracture.** (Sept., 485–489; 489–492). V. External tensile or compressive stresses, within the elastic limit, applied to cold-worked Armco iron, produced unification of hardness and structure, some recovery of magnetic properties and reduction of residual stress. VI. Under tension, fracture in Armco rods and plates starts with a crack at the centre of the smallest section of the neck and travels rapidly towards the outer surfaces.—K. E. J.

Quantitative Calculation by Dilatometric Curves of the Stages of Deformation in Steel. Yu. A. Kocherzhinskii. (*Zavods. Lab.*, 1958, (4), 437–439). The method by which the quantity of the phase in course of transformation is determined by the ordinate between the extrapolated line characterizing the pure thermal change of dimensions of the specimen and the actual dilatometric curve does not give correct results, since the ordinates diminish whilst the quantities of austenite do not. The new method suggested takes account of the specific volume and length of specimen in the α- and γ-states and also of the actual specific volume and length of the specimen, but it also requires the specific volume and proportion of carbides, which can only be determined dilatometrically under certain specified conditions which are explained.—L. H.

Changes in Properties of Mild Steel Caused by Stress-ageing Treatment. III. On the Effects of Pre-working Temperature and Cooling Method. T. Sakurai, T. Kawasaki, and H. Izumi. (*Nippon Kinzoku*, 1956, **20**, June, 300–304). The higher the stress applied, the more effective the hardening, although tensile strength and yield point are hardly affected by intensity of stress. Pre-straining at 250–500° C before stress-ageing at the same temp. increases the hardness and static strength considerably. The most effective way of improving static strength is to heat the specimen at approx. 400° C, to apply a load to produce plastic deformation and to cool rapidly under load. **IV. On the Influence of Pre-Treatments.** (Sept., 492–496). Details are given of the improvement in various mechanical properties of mild steel quenched from 700° C and spheroidized mild steel produced by stress-ageing; the effects are greater than with annealed steel.—K. E. J.

Study of the Elevated Temperature Plastic Deformation of a Soft-Iron and of a Stable Nickel-Iron Austenite. R. Tamhankar, J. Plateau, and C. Crussard. (*Rev. Mét.*, 1958, **55**, Apr., 383–400). The elevated temperature mechanical properties and structural modifications accompaning deformation have been studied by means of tensile, torsion, creep, and internal friction tests on two single phase steels—an austenite of very low carbon content with 35% Ni and 10% Cr and a decarburized Armco iron. Slip and intercrystalline decohesion become preponderant above the equicohesive temperature. This temperature was easily determined for the austenitic steel but is not apparent with the iron. Interpretation of the results obtained with the steel by microscopical and X-ray examination made it possible to establish the part played by intercrystalline slip, by slip and diffusion of grain boundaries, by polygonization and by recrystallization.—B. G. B.

Effect of Strain Hardening on the Mechanical Properties of Carbon Steels. I. V. Kudryatsev, T. V. Naumova, and L. M. Rozenman. (*Metallov. Obra. Met.*, 1958, (3), 2–6). Large plastic deformations (65–120% elongation) increase hardness, yield point and U.T.S., and ductility is lowered, but only slightly as measured by reduction in area. Impact values are lowered for some steels at all temperatures examined (to 600°). Impact endurance of smooth specimens increases while that of notched specimens slightly decreases. On heating to 300° C hardness is further increased and impact strength lowered. Heating to 800° eliminates the effects.

Effect of Technological Factors on the Depth of Strain Hardening in Grinding. Yu. S. Terminasov and A. G. Yakhontov. (*Metallov. Obra. Met.*, 1958, (5), 40–43). After grinding the altered layers were removed electrochemically and microhardness measurements were made. X-Ray studies also detected lattice distortions. The strain-hardening was found to extend much further than the depth of grinding. A simplified scheme of forces is examined and used to relate grinding conditions to distortions produced.

Measurement of Residual Stresses in Alloy Steel Forgings. A. Barker and E. H. Hardy. (*Proc. I.M.E.*, 1957, **171**, (17), 581–596). An examination of the trepanning method and of the Sachs method is reported and a strain gauge technique is described. Probable errors are estimated.

Residual Stresses in Steel Wires. T. Nishioka. (*Nippon Kinzoku*, 1956, **20**, Aug., 424–427). [In Japanese, with German summary]. By etching in 10% HNO_3 the surface is removed and change of length is measured giving longitudinal strain. Patented wire showed only small residual stresses but as-drawn the stress was high. Stresses are related to drawing conditions and temperature.

Residual Stresses in Steel Wires. T. Nishioka. (*Nippon Kinzoku*, 1957, **21**, Sept., 540–544). The effect of a reduction of less than 10% on residual stresses in air-patented steel wires was investigated. For reductions of less than 7% the residual stresses were compressive in

the surface and tensile in the core, and vice versa above 7%. Compressive surface stresses were largest for a reduction of 0·7%. Light drafts brought about a higher endurance limit in reversed bending.—J. G. W.

Fatigue Failure Diagram for Metals. V. S. Ivanova. (*Doklady A.N.*, 1958, **119**, (1), 71–74). Three fatigue periods are distinguished: (1) An incubation period during which the processes take place along grain boundaries; (2) A loosening period with the appearance and development of submicroscopic cracks in the slip bands, and (3) A destruction period. An experimental diagram for ARMCO-iron and Cu is constructed on co-ordinates—stress against log number of cycles. In this diagram three curves delimit the three periods.—S. I. T.

Study of Some Laws Relating to Fatigue Processes in Metals. V. S. Ivanova. (*Rev. Mét.*, 1958, **55**, June, 562–566). After outlining the results of recent work on fatigue, the author proposes a fatigue diagram in which three stages can be distinguished, namely incubation, characterized by the absence of slip bands visible under the optical microscope; adaptation, and the initiation of cracks. A method for the determination of the length of each period is described, and an experimental fatigue diagram for Armco iron is reproduced.

Fatigue Studies of Quenched and Tempered Nodular Iron. P. E. Goettsch. (*U.S. Dept. Commerce, PB* 131495, 1956, Oct., pp. 18). Nodular irons of identical composition quenched and tempered to five hardness levels were tested for unnotched fatigue strength and endurance ratio. The ratio was found to decrease as hardness and tensile strength increase, an approximately linear relationship was found between u.t.s. and endurance ratio and secondary graphite nodules had no adverse effect on fatigue properties.

Monographs on Fatigue Failures. Investigation of Damaged Parts of Vibrator Units. (*Soud. Techn. Connexes*, 1958, **12**, May-June, 184–186). [In French]. The behaviour of parts vibrating at 10 000 strokes/min is described. Cracks were found at the welded junction between a 0·5% C steel tube and a 3% Ni steel tip. Failures are shown to be due to the very strong vibrations sustained by the unit and to defective welding.—M. D. J. B.

Fatigue Test Results with Shouldered and Force-fitted Large Specimens. N. Oda and K. Nishioka. (*Sumit. Met.*, 1958, **10**, Jan., 37–44). Fatigue results are given for various sizes of railway car axles where stress concentrations occur, and acceptable design figures are given for fatigue strength reduction factors in the cases of shouldered and force-fit specimens. (12 references).—K. E. J.

Relation between Direct-Stress and Bending Fatigue of High-Strength Steels. G. Sachs and G. Scheven. (*Proc. A.S.T.M.*, 1957, **57**, 667–681). Tests on SAE 4340 heat-treated to several strengths were made. *S–N*-curves extrapolated well to static strength as origin. Bend-strength and notch-strength ratios are determined, the former for large numbers of cycles being ∼ unity while for small numbers it is > 2 for smooth and 1–2 for notched specimens depending on ductility. Notch-strength ratio is ∼ 0·3 for high numbers of cycles and gradually increases with lower numbers to static values. These are lower for bending than for tension for notch-sensitive steels.

Axial-Load Fatigue Properties of High-Strength Steels. B. B. Muvdi, G. Sachs, and E. P. Klier. (*Proc. A.S.T.M.*, 1957, **57**, 655–666). Complete reversal fatigue tests were carried out on Tricent, Cru UHS–260, and Super TM–2 steels heat-treated to strength levels of 250 000–300 000 psi. Notch-sharpness, strength level, and specimen orientation were examined. Fatigue strength was lowered as the stress-concentration factor increased with the greatest effect at factors between 1 and 3 and the effect depended upon strength level. Endurance limit was lower for transverse specimens and more pronounced for smooth than for notched specimens and decreased with reduced strength levels.

Fatigue Strength of Some Machine Parts and a Detailed Examination of the Scatter of the Results. L. Locati. (*Rev. Mét.*, 1958, **55**, Apr., 364–374). The results are given of a comprehensive investigation of the scatter of fatigue tests. The use of the information for compiling acceptance limits for components is discussed.

Effect of Grinding Conditions and Resultant Residual Stresses on the Fatigue Strength of Hardened Steel. L. P. Tarasov, W. S. Hyler, and H. R. Letner. (*Proc. A.S.T.M.*, 1957, **57**, 601–622). Flat test bars were ground longitudinally with wheel hardness, grinding fluid and downfeed as variables. Reversed bending showed that for good commercial conditions the fatigue limit was the same as for gentle grinding. Severe grinding depressed the limit about 13% whereas some grinding with straight grinding oils gave increases up to 38%. An appreciable range in residual peak tensile stress (up to ∼ 50 000 psi) for which fatigue limit remained substantially at base-line value. Above this stress a reduction occurred.

Influence of Notch Preparation and Eccentricity of Loading on the Notch Rupture Life. M. H. Jones, J. L. Shannon jun., and W. F. Brown jun. (*Proc. A.S.T.M.*, 1957, **57**, 833–853). Cr–Mo–V steel 17–22A(S) and superalloy A–286 were used. The former was practically independent of method of notch preparation at 1000° F but the latter at 1200° F was influenced to some extent.

The Fatigue Behaviour of Decarburized Steel. H. A. Lipsitt and G. T. Horne. (*Proc. A.S.T.M.*, 1957, **57**, 587–600). Tests in completely reversed axial tension–compression were made on mild steel in the hot-rolled condition and after decarburization. Rotating beam tests were also made and data are discussed in the light of a strain-ageing process to account for differences. The methods of testing are shown. Partial removal of C and N reduces life at a given stress and also reduces fatigue limit. Complete removal ought to suppress the fatigue limit to lifetimes approaching non-ferrous behaviour.

Cyclic Strain Fatigue Studies on AISI Type 347 Stainless Steel. E. E. Baldwin, G. J. Sokol, and L. F. Coffin jun. (*Proc. A.S.T.M.*, 1957, **57**, 567–586). Constant-temperature tests are reported for the range 0·0035–020 in. per in. Temperatures up to 600° C were used and grain size, anisotropy and effects of sequential loading were examined. An expression is given in terms of which the results were interpreted.

Fatigue Under Fretting Conditions. A. J. Fenner and J. E. Field. (*Rev. Mét.*, 1958, **55**, May, 475–485). Fretting was produced by direct stress fatigue tests on Al alloy and mild steel specimens under various conditions of clamping. For Al alloys the resultant reduction in fatigue strength was proportional to the relative movement between clamp and specimen. Mild steel seems relatively insensitive to clamping.—A. G.

Fatigue of Aircraft Structures. (*A.S.T.M. S.T.P. No.* 203, 1957, Nov., pp. 100). Methods of testing of stainless steel and various non-ferrous alloys are described. The effects of stretching and bending on static and fatigue strengths of sheet metals including 302 stainless are described and discussed by J. L. Waisman and C. S. Yen.

Effects of Hydrogen on Low-Cycle Fatigue of High-Strength Steels. G. Scheven, G. Sachs, and K. Tong. (*Proc. A.S.T.M.*, 1957, **57**, 682–697). SAE 4340 steel was used at strength levels of 210 000–290 000 psi. Rotating bend tests on notched and smooth specimens were done as-heat-treated and H_2-embrittled (after Cd plating). The effect on fatigue life and crack propagation was examined from 5–10 000 cycles. Effects were erratic but the life was usually reduced, especially at strengths of 230 000–270 000 and at low cycling rates. Fracture appearance and crack propagation were greatly influenced by H_2.

Properties and Fatigue Strength of a Metallized Copper Surface. J. Salokangas and P. Lehto. (*Soud. Techn. Connexes*, 1958, **12**, May-June, 173–181). [In French]. The authors describe research into the behaviour of a Cu layer sprayed on the rolls of paper machines. Fatigue tests show that the coating can sustain repeated loads of the order of 10^5 cycles. The quality of the deposit depends largely on the speed with which the metal is deposited and on the distance from which it is sprayed.

Development and Construction of Creep-Testing Machines. P. Jehlička and R. Schönhoffer. (*Vyzkumne Prace z Oboru Železa a Oceli*, 1958, 197–207). Existing designs are evaluated and a standard machine is constructed.

Analysis of the Phenomenon of Creep on the Basis of Static Tensile Tests. J. Wantuchowski. (*Arch. Hutn.*, 1958, **3**, (3), 201–225). Creep tests starting at different initial rates may have quite different courses. The effect of method and rate of loading is examined with a modified static test machine. An ordinary test is started and at a predetermined value creep sets in, the load is then kept constant and extension is precisely followed. By making the preliminary rate of loading different up to the same constant stress the effect of speed of loading is found. An equation for deformation is given and tested on Cu, Ag, and Monel. The initial loading took 16 min to 9 days and the creep about 2 days.

A New Rheological Model of Creep. C. Crussard. (*Rev. Mét.*, 1958, **55**, Apr., 375–382). A new rheological model is proposed comprising viscous centres of creep which interact elastically on each other. Application of a force to one of these centres causes the appearance of a transient order and a stationary regime. The calculations reproduced show that the transient regime is represented by a summation of exponential terms to which the parabolic laws observed in practice provide a very close approximation.—B. G. B.

Creep Tests with Multi-Sample Equipment at Temperatures above 500° C. II.—Effect on the Creep-Behaviour of Heat-Resistant Materials. H. Wiegand and H. Reiner. (*Metall*, 1958, **12**, Sept., 803–810). Short-time creep tests in multi-sample apparatus (up to 200 samples) of heat-resistant ferrous metals showed irregularities in the results with respect to the strain/time curves. It was found that these irregularities are not caused by the testing equipment but by the material itself and that they decay after a testing time of about 20 000 h, i.e. creep tests should extend over 50 000–100 000 h. Short-time tests lead to wrong predictions of the creep properties in service. The results are presented in many graphs.

On the Representation and Extrapolation of Creep Data of Metals and Technical Alloys. P. Feltham and J. D. Meakin. (*Rheologica Acta*, 1958, (2/3), 176–179, reprint). From a detailed analysis of the creep data for Nimonic 90 it is suggested that fracture times be represented as a function of the minimum equilibrium creep rate in log–log co-ordinates. The theoretical significance is considered.

Constant-Stress Creep Rupture Tests of a Killed Carbon Steel. P. N. Randall. (*Proc. A.S.T.M.*, 1957, **57**, 854–872). Equipment is described which maintains constant stress throughout, provides for maintenance of axiality, records continuously and controls temperature through a servo-system. Stress rupture and true strain rate versus time data are presented for 40 pairs of specimens tested at 5 temperatures between 800–1200° F and for 0·05–15 000 h. Two minima were found in creep rate in the longer tests at lower temperatures. This is thought to be due to strain ageing.

On Dynamic Creep with Special Consideration of Strain Rate Effects. F. H. Vitovec. (*Proc. A.S.T.M.*, 1957, **57**, 977–986). Theoretical analyses of strain rate effects in dynamic creep are presented. (24 refs.).

Creep Studies on Austenitic and Alloy Steels. K. Bungardt. (*Forsch. Wirts. Nordrhein-Westfalen*, 1958, No. 456, pp. 63). Studies of Cr–Ni and Cr–Mo–Ni with Nb, Ti, V and N, Cr–Ni–B, and Cr–Ni–Co steels, Cr–Ni–Co–Fe alloys and Ni alloys are reported, with numerous tables.

Pure Torsion Creep Tests on Magnesium Alloy (2% Al) at 20° C, and on 0·2% C Steel at 450° C, at Low Rates of Strain (10 $^{-6}$ to 10 $^{-9}$ per Hour). A. E. Johnson, J. Henderson, and V. D. Mathur. (*Metallurgia*, 1958, **58**, Sept., 109–117). The steel in question was cast, creep strain showed a time-dependence which does not alter throughout the range of

creep rates concerned. In addition, the stress dependence included a term of unit stress dependence becoming increasingly dominant at lower rates, representing a recoverable element of creep which appeared to be fairly well represented by a Boltzmann superposition principle.

An Experimental Study of Compressive-Creep Behaviour at Elevated Temperatures. R. L. Carlson and E. G. Bodine. (*Proc. A.S.T.M.*, 1957, **57**, 898–905). Strain/time curves were found for Al alloys.

Effect of Prior Creep on Mechanical Properties of Aircraft Structural Metals. (2024–T86 Aluminium and 17–7PH Stainless). J. V. Gluck, H. R. Voorhees, and J. W. Freeman. (*WADC Techn. Report* 57–150. *Part I; ASTIA Document No. AD* 150956; *PB* 131716–250, 1958, Feb., pp. 106). Stresses giving up to 3% total deformation were applied for 10, 50, and 100 h at 600° and 900° F to the steel. Mechanical tests were then carried out when changes were found which might show increases or decreases according to conditions. After 100 h creep near 600° F a fall in ductility appeared to occur.

Some Causes of Damage and Cracks in Rails. J. Lesiecki, J. Rys, and S. Rudnik. (*Hutnik*, 1957, **24**, Nov., 457–462). [In Polish]. Results of investigations show that cracks originating in the base of the rail are caused by defects acquired during the process of rolling. Numerous non-metallic inclusions and gas bubbles were found under the surface near the cracks. Various other types of cracks and damages are described, shown on photographs, and discussed in detail.

On the Strength of the Tyre Tread. N. Oda and K. Nishioka. (*Sumi. Met.*, 1958, **10**, Apr., 81–92). The spalling or shelling of railway rolling stock tyres was examined. Contact pressures are calculated, plastic deformation was studied and the mechanism of cracking was described. Stress from shrink-fitting appears to have little effect. A residual compressive stress near the surface may increase the strength.

A Hardness Nomogram for Grey Cast Iron. H. H. Wahl. (*Giesserei*, 1957, **44**, Dec. 5, 746–747). A brief article which first reviews the literature on the various relationships between different cast phenomena (7 references). These relationships are considered and fresh equations calculated, relating such quantities as the wall thickness of the mould, the 'carbon-plus-¼-silicon' content, the phosphorus content and the hardness of a cast iron (unalloyed). A nomogram for rapid calculation of any of these quantities is constructed and an example given of its use.—R. J. W.

Rheological Aspect of Hardness. A. Braun. (*Rev. Mét.*, 1958, **55**, May, 470–474). The need to define hardness in relation to elasticity, plasticity and viscosity is stressed. A specific hardness function is derived which makes possible a more detailed analysis of the rheological properties of a solid.—A. G.

Ferrite Grain Size and Hardness of Electric Resistance-Welded Pipe after Cold Working and Annealing. T. Yamamoto. (*Sumit. Met.*, 1958, **10**, Jan., 5–8). Recrystallization occurs at the annealing temp. of 600–700° C. The tendency to grain growth is almost parallel to carbon content. Grain growth is greatest with cold reduction of approx. 10%. Both the welded portion and the matrix have similar tendencies to recrystallization. The reduction in grain size is greater with higher degrees of cold reduction.—K. E. J.

The Influence of Carbon and Hardening Temperature on the Hardness of Martensite. A. N. Rozanov. (*Doklady A.N.*, 1957, **115**, (4), 721–722). Microhardness of dark and light martensite needles (hardened and self-tempered steel) for various carbon contents was determined, and the influence of hardening temperature on the hardness of martensite and the hardness of sub-eutectoid and trans-eutectoid steel was determined.—S. I. T.

A Study of Microhardness. F. Muñoz del Corral and L. Alonso Yagüe. (*Inst. Hierro Acero*, 1958, **11**, Apr.-June, 128–137). [In Spanish]. By means of tests on different materials (copper, hardened steel, and transformer sheet) in various conditions, it is found that most of the variations in microhardness value with load, especially with very small loads, is due to the different properties of the surface layers. Specimen preparation can cause disturbance to appreciable depths. As these surface disturbances are eliminated so the load necessary to give microhardness values equal to the microhardness values decreases.—P. S.

Microhardness Testing at High Temperatures. J. H. Westbrook. (*Proc. A.S.T.M.*, 1957, **57**, 873–897). A tester of modified Bergh design is described with a temperature range of 20–1500° C and a load range of 20–900 g. Problems encountered, especially with hard, brittle materials are discussed.

Using Microhardness for the Determination of the Hardening of Structural Steels in Cold-Working and Ageing Deformation. K. M. Pogodina-Alekseeva, and E. E. Krotkova. (*Zavods. Lab.*, 1958, (4), 470–473). The data of microhardness are used in the investigation of the effect of the static and dynamic compression deformation on the subsequent mechanical ageing of structural steels. The conclusions reached are that microhardness is a simple and sufficiently accurate method of investigating the changing properties observed in these steels under such conditions.—L. H.

Investigations on the Ageing Tendency of Soft Unalloyed Steels by Hardness Testing up to 300° C. F. Wever and W. Wepner. (*Forsch. Wirts. Nordrhein-Westfalen*, 1956, No. 227, pp. 24). The hardness is shown to depend on nitrogen content and to a smaller extent, on carbon.

Properties of Open-Hearth and Bessemer Seamless Pipe. A. B. Wilder and W. P. Benter. (*Proc. A.S.T.M.*, 1957, **57**, 731–750). Basic O.H. and acid Bessemer steels were rolled into seamless pipe and ageing properties, after cold work and after quenching were compared, also fatigue, impact, and high-temperature tensile tests were carried out. Welding properties and strength of welds were also examined. The properties of Grade B steels were similar. The superior properties of deoxidized acid Bessemer steel were shown.

Ductility and Energy Relations in Charpy Tests of Structural Steels. J. H. Gross and R. D. Stout. (*Weld. J.*, 1958, **37**, Apr., 151s–159s). The correlation between the resistance of steel to brittle fracture in low temperature service and either the Charpy V-notch energy absorption or the notch ductility (as measured by the lateral expansion of the Charpy specimen at the side opposite to the notch) is discussed. Data are presented to show that energy absorption depends on both tensile strength and notch ductility, and that there is a linear correlation between the fracture energy corresponding to a given expansion and the tensile strength. It is concluded that lateral expansion is so readily measured that it could conveniently be specified directly as a criterion for resistance to brittle fracture in place of a variable level of energy absorption dependent on the steel type.—B. C. W.

Charpy Brittle-Fracture Transitions by the Lateral Expansion—Energy Relationship. G. M. Orner. (*Weld. J.*, 1958, **37**, May, 201s–205s). Data are presented to show that the temperature corresponding to a discontinuity in the plot of lateral expansion at the compression face of Charpy V-notch specimens against energy-to-fracture (from conventional single blow tests) corresponds quantitatively with the low blow transition temperature, provided that the effects of the adiabatic temperature rise during testing is taken into consideration.

Process of Carbide Formation in Steel Tempering as Related to Reversible Temper Brittleness. L. M. Utevsky. (*Doklady A.N.*, 1958, **119**, (1), 79–82). A review of recent work on this subject is given. The influence of various elements on the properties of ferrite, the segregation hypothesis of Arkharov, the destruction of steel along boundaries of the original austenite grains, and other problems are discussed. (25 ref.).—S. I. T.

Study of the Behaviour of Aged 11–20% Chromium Steels in the Temperature Range Around the 475° C Embrittlement. E. Baerlecken and H. Fabritius. (*Stahl Eisen*, 1958, **78**, Oct. 2, 1389–1395). Heating the steels in the 475° C range showed from bending, impact, corrosion, and creep tests that the Cr content should not exceed 12·8%. When other elements are added, the critical Cr content is reduced to 12%. High carbon contents reduce the tendency to brittleness by chromium carbide formation, stronger carbide formers such as titanium and niobium promote it. The temperature at which the worst embrittlement occurs decreases with decreasing Cr content. Low-Cr steels under stress embrittle more at temperatures below 475° C than above this temperature. Steels containing 13 or 14% Cr can be stressed for long periods at 500° C without any risk of embrittlement.—T. G.

Present Knowledge Regarding Brittle Failure of Steel in Welded Constructions. C. Miclosi. (*Met. Constr. Masini*, 1958, (5), 399–405). [In Rumanian]. A report presented at the General Scientific Session of the Research Section of the Academy of Temisoara which reviews the present day knowledge of conditions which lead to brittle failure in welded steels and which emphasizes the gaps in that knowledge which still require investigation.—L. H.

Study of an Instance of Intergranular Fragility in Iron. C. de Beaulieu. (*Rev. Mét.*, 1958, **55**, May, 495–499). The conditions of temperature, atmosphere, and time of annealing which produce brittleness in lightly work-hardened specimens of Armco iron have been established. A brief heating above the A_3 point removes this brittleness. Various explanations of the phenomenon are discussed.

Effects of Physical Variables on Delayed Failure in Steel. R. D. Johnson, H. H. Johnson, J. G. Morlet, and A. R. Troiano. (*WADC Tech. Report* 56–220, 1956, June, pp. 37). Effects of H_2 distribution, test temperature and prestressing were measured for hydrogen-induced brittle fracture of 4340 steel in static failure. Crack propagation was measured by electrical resistance. Crack propagation was found to be sensitive to H_2 distribution but not to applied stress. Internal cracks appeared even in notched specimens and propagation appeared to be diffusion-controlled. Pre-stressing tended to reduce the delayed failure phenomenon by raising the necessary stress range.

Influence of the Times of Charging and of Maintaining the Atmosphere on Hydrogen Brittleness in Steels. J. Plusquellec, P. Azou, and P. Bastien. (*Compt. Rend.*, 1958, **246**, June 23, 3 454–3 457). Results show that there are two anomalies of maximum brittleness for times of charging between 8 and 32 h, corresponding to 'soaking' times of 10 min and 1½ h. Factors governing this and other phenomena are being studied.—A. G.

The Recovery of Embrittled Cadmium Plated Steel. H. H. Johnson, E. J. Schneider, and A. R. Troiano. (*WADC Techn. Report* 57–340; *ASTIA Document No.* AD 142244; *PB* 131654–075, 1957, Dec., pp. 17). Plating thickness influences recovery rate. A thin Cd deposit is produced and the hydrogen removed by baking; a second plating treatment can then be applied, the original coating preventing the entry of hydrogen.

Crack Propagation Tests of High-Strength Sheet Steels Using Small Specimens. J. E. Srawley and C. D. Beachem. (*NRL Report* 5127; *P.B.* 131682–100, 1958, Apr. 9, pp. 28). A test for sheet materials to distinguish those sensitive to minute stress raisers is described. Small specimens with a central transverse crack are used, and they must be sensitive to H_2 embrittlement. 410 and 422 stainless steels are distinguished by the test. Thin sheets have relatively higher net fracture stress and possibly laminated sheets of more brittle materials could be used.

Effect of Fabricated Edge Conditions on Brittle Fracture of Structural Steels. L. A. Harris and N. M. Newmark. (*Weld. J.*, 1958, **37**, Apr., 137-s). A summary. Machined, sheared, flame-cut, and flame-cut and softened edges were examined.

The Problem of Wear and the Sulfinuz Process. F. Barbas. (*Usine Nouv.*, 1958, July, monthly Ed. 57, 59, 60, 61, 63, 65, 67, 68). The mechanism of abrasion is reviewed and its measurement described. The properties of

S, the sulfinuz surface sulphiding process, and the properties of the treated ferrous surfaces are given. Copper alloys can also be used.

Surface Layers Deformations Due to Sliding Friction. A. S. Radchik and V. S. Radchik. (*Doklady A.N.*, 1958, **119**, (5), 933–935). Experiments were made on the determination of sliding friction with metallic surfaces of unequal size and also on rollers made of steel, and characteristic oscillograms show that the high wear of the surface with a variable contact is due to the change of the sign of deformation.—S. I. T.

Frictional Heating and Its Influence on the Wear of Steel. N. C. Welsh. (*J. Appl. Phys.*, 1957, **28**, Sept., 960–968). Dry wear tests on steels of various compositions were carried out. The high frictional temperatures produce hardening of the surface layers, the more rapidly as C content increases representing the ferrite → austenite → martensite change. By spark simulation of the wear process it was shown that hardness is intensified by N_2 or C absorbed from atmosphere or lubricant.

Investigation of Temperature Stability of Deformational Distortions and the Kinetics of Weakening of the Friction Surfaces. K. V. Savitzkii and M. P. Zagrebennikova. (*Doklady A.N.*, 1958, **119**, (3), 490–493). Experiments were carried out on samples of polycrystalline copper annealed at temperatures varying from 200° to 450° C with slip under pressure. The relation between microhardness and the time of annealing, as expressed by curves, shows that for all temperatures microhardness falls rapidly at first and then usually becomes parallel to the time axis. Curves showing the relations of weakening of surfaces, intensity of weakening, and the influence of normal load, to the time of annealing, are also given.—S. I. T.

Variation of the Optical Properties of Iron at Transition Temperature. A. Kinbara. (*J. Phys. Soc. Japan*, 1958, **13**, Aug., 966). Light emitted from a heated plate shows a change in polarization ratio at the transition near 910°.

Magnetic Study of Age-hardening of Iron–Molybdenum Alloys. I, II. T. Mishima, R. Hashiguti, and Y. Kimura. (*Nippon Kinzoku*, 1956, **20**, Mar., 165–169; 169–173). I. For a Fe–Mo alloy containing 20% Mo, changes in various properties with ageing time can be expressed by the Austin-Rickett formula. The activation energy of the ageing process is 75·6 kcal/mole. The relation between the volume of ppt. and the measured properties is explained theoretically. (20 references). II. In the alloy containing 15% of molybdenum, the activation energy is 72 kcal/mole. Changes during ageing can be described using the Austin-Rickett equation, the Johnson-Mehl equation, and Néel's theory.—K. E. J.

The Dependence of Coercive Force on Temperature for Thin Specimens of Nickel and Iron–Nickel Alloys. E. Kondorskii and M. Rosenberg. (*Doklady A.N.*, 1958, **120**, (4), 753–756).

The Influence of the Magnetic Field on the Strength Properties of Ferromagnetics. H. Jahn. (*Technik*, 1958, **13**, Feb., 94–99). Recent findings concerning the effects of irradiation and of magnetic fields on the properties of ferromagnetics are surveyed. Attention is drawn to the possible use of intense magnetic fields in the presence of cooling, in raising the level of mechanical properties of treated straight-carbon steels to that of high grade alloys.—J. G. W.

Coercive Force *vs* Thickness for Thin Films of Nickel-Iron. C. O. Tiller and G. W. Clark. (*Phys. Rev.*, 1958, **110**, Apr. 15, 583–585).

Magnetoresistance Coefficients and Their Temperature Dependence in Iron and Silicon-Steel. E. Tatsumoto. (*Phys. Rev.*, 1958, **109**, Feb. 1, 658–662).

Magnetostriction of Aluminium Iron Single Crystals in the Region of 6 to 30 Atomic Percent Aluminium. R. C. Hall. (*J. Appl. Phys.*, 1957, **28**, June, 707–713).

Magnetic Domain Patterns on Single-Crystal Iron Whiskers. R. V. Coleman and G. G. Scott. (*Phys. Rev.*, 1957, **107**, Sept. 1, 1276–1280).

Slow Remagnetization Times in 4–79 Molybdenum Permalloy. J. D. Blades and R. A. Tracy. (*J. Appl. Phys.*, 1957, **28**, Apr., 516).

Magnetization of Ilmenite–Haematite System at Low Temperatures. R. M. Bozorth, D. E. Walsh, and A. J. Williams. (*Phys. Rev.*, 1957, **108**, Oct. 1, 157–158).

I–T Diagrams of Hungarian Standard Steels. I. Mester and A. Szombatfalvy. (*Koh. Lapok*, 1958, **13**, April, 168–173). After a short review of various methods for the determination of I–T diagrams, the authors describe in detail a magnetic method used in the Hungarian Iron and Steel Research Institute.

Ultrasonic Testing—Work Carried out in France in Conjunction with the Institute of Welding. P. Bastien. (*Soud. Techn. Connexes*, 1958, **12**, May-June, 187–188). [In French]. A survey is made of ultrasonic testing practice in France. Investigations carried out on reference pieces are described and an interpretation is given of the various types of welding defects. Various types of testing equipment are examined and a glossary of terms used in ultrasonic testing techniques is given.

Sheet Testing by the Method of Penetration. I. Egri. (*Polish acad. Sci. Proc. II Conference on Ultrasonics*, 1957, 123–129). [In English]. Ultrasonic submerged testing was used and the new method is described. Limits of flaw detection and margin of error are determined.

Comparison of Detectability by Means of the Ultrasonic Method and the X-Ray Method in the Testing of Welded Joints. Z. Pawlowski and M. Radwan. (*Polish acad. Sci. Proc. II Conference on Ultrasonics*, 1957, 175–178). [In English]. The ultrasonic method was found to be simple and rapid. For single inclusions and minute blowholes, X-rays are superior.

X-Ray Control of Steel Welds. R. Grabovski and A. Bancila. (*Met. Constr. Masini*, 1958, (5), 412–420). [In Rumanian]. The welds are submitted to X-ray control after their exterior surface defects have been eliminated (polishing etc.). For routine control, one X-radiograph with beam perpendicular to the surface suffices. The control is limited by the sensitivity of reproduction and by the possibility of correct projection on to the seams.—L. B.

X-Ray Determination of the Number of 3*d* Electrons in Cu, Ni, Co, Fe, and Cr. R. J. Weiss and J. J. De Marco. (*Rev. Modern Phys.*, 1958, **30**, Jan., 59–62). For body-centred cubic iron the value was $2{\cdot}3 \pm 0{\cdot}3$.

Industrial Radiography with Radioisotopes: Comparison of X-Ray Radiography with Gamma-Radiography—Impressions of a Visit to the U.S.A. O. Werner. (*Metall*, 1958, **12**, Sept., 799–802). The author reviews impressions of a visit to the U.S.A. for studying industrial radiography. He points out the advantages and shortcomings, limitations, times of exposure and costs of installations for X-ray and γ-ray radiography. A clear decision in favour of one of the two methods cannot yet be made, in many cases the use of X-rays is to be preferred, particularly if 2 000-kV equipment is employed, in spite of the very high capital outlay.—T. G.

Radiography. Gammagraphy. Methods and Equipment. Coinde, Vialle, and Tirard. (*Centre Doc. Sidér. Circ.*, 1958, (4), 871–884). A review is given of the use of radioactive isotopes, X-rays, and the betatron (high intensity X-rays) for non-destructive testing.

Symposium on Radiation Effects on Materials. Vol. 2. Amer. Soc. Testing Mat. and Atomic Industrial Forum. (*A.S.T.M.S.T.P.*, No. 220, 1958, Feb., pp. 137). Structural materials for nuclear power plants as well as fuel elements, organic materials, and semiconductor devices are considered. Stainless steel data are tabulated and techniques of tensile testing at elevated temperatures are described by W. S. Kelly, D. C. Kaulitz, and R. E. Hueschen, and remote metallographic equipment at the Hanford plant by J. R. Morgan.

Depth Variation of Tritium and Argon-37 Produced by High-Energy Protons in Iron. E. L. Fireman and J. Zähringer. (*Phys. Rev.*, 1957, **107**, Sept. 15, 1695–1698).

Total Neutron Cross Sections of Mg, Al, Fe, Cu, Zn, Mo, and Pb from 4 to 8 Mev. J. L. Weil and K. W. Jones. (*Phys. Rev.*, 1958, **110**, Apr. 15, 466–467).

Critical Magnetic Scattering of Neutrons by Iron. R. D. Lowde. (*Rev. Modern Phys.*, 1958, **30**, Jan., 69–74).

Scattering of Neutrons by Spin Waves in Magnetite. B. N. Brockhouse. (*Phys. Rev.*, 1957, **106**, June 1, 859–864).

Positron Polarization Demonstrated by Annihilation in Magnetized Iron. S. S. Hanna and R. S. Preston. (*Phys. Rev.*, 1957, **106**, June 15, 1363–1364).

Thermal Shock Resistance of High Temperature Alloys. F. L. Muscatell, E. E. Reynolds, W. W. Dyrkacz, and J. H. Dalheim. (*Proc. A.S.T.M.*, 1957, **57**, 947–964). Apparatus simulating gas-turbine conditions is described and tests on superalloys and stainless steels are reported. Wrought alloys were more resistant than cast, and Co-base than Ni or Fe-base alloys.

Thermal Shock Testing Under Stress of Certain High Temperature Alloys. F. K. Lampson, T. C. Tsareff jun. and A. W. F. Green. (*Proc. A.S.T.M.*, 1957, **57**, 965–976). Fifteen Fe-base and 6-Co-base alloys were tested by applying stress and heating and cooling rapidly and continuing cycling to failure (or to a fixed number of cycles). All materials tried showed good resistance at 1 200–1 800° F. Fractures were of intergranular type and preferential oxidation preceded failure.

Coefficients of Linear Expansion of Diluted α-Solid Solutions of Fe with Cr, Mo, and W. Yu. G. Miller. (*Doklady A.N.*, 1958, **119**, (3), 488–489). It is shown experimentally that in the case of Fe–Cr with 4·25 at.-% Cr, there is a linear relation between the coefficient of linear expansion and the temperature (250° to 850° C). Curves of linear expansion as a function of the second metal percentage for Fe–Cr, Fe–Mo, and Fe–W alloys show distinct minima, which vary from 0·05 to 0·15 at.-%.

Selected Properties of Structural Materials at Elevated Temperatures. D. A. Shinn. (*N.A.T.O. Advisory Group for Aeronautical Research and Development, Report* 104, 1957, Apr., pp. 40). Mechanical properties important in design are given, mainly for Ti alloys.

Preliminary Studies on the Evolution of Fumes from Iron at High Temperatures. E. T. Turkdogan and L. E. Leake. (*JISI*, 1959, **192**, June, 162–170). [This issue].

Influence of Treatment by Cold on Some Mechanical Properties of High-Alloy Case-Hardened Steels. Yu. G. Vyshkovskii and A. A. Yurgenson. (*Metallov. Obrabotka Met.*, 1957, (10), 33–36). The author discusses available evidence on the sometimes deleterious effects of treatment by cold on high-alloy steels, such as 18KhNVA after case-hardening and gives results of his experiments. In these, 30 polished 10 × 10 × 120 mm specimens of this steel were case-hardened to a depth of 0·8 mm after which some were cooled in oil, others air cooled in the boxes. All specimens were then held at − 78° C for 3 h and then at 150° C for 2 h and bend tested with and without grinding the faces to depths of 0·05 and 0·10 mm. The results showed that rapid cooling after case hardening improves the mechanical properties as does removal of the hardened layer. The author discusses the significance of the results.—S. K.

Effect of Subzero Treatment on the Hardness and Magnetic Properties of High-Carbon High-Chromium Steel. S. Koshiba and T. Nishinuma. (*Nippon Kinzoku*, 1956, **20**, Mar., 135–138). [In Japanese]. Subzero treatment at − 72° produces a change of retained austenite to martensite after quenching, with increases in magnetic saturation and residual magnetism. The lower the treatment temp., the more austenite is decomposed. The hardness is increased to RC 50–55 by subzero treatment after normalizing at 1 150° C.

Measurement of the Activation Energy of the Intergranular Autodiffusion of Iron in the Alpha Phase, with the Help of Radioactive Tracers. C. Leymonie, P. Lacombe, and C. Libaniti. (*Compt. Rend.*, 1958, **246**, May 5, 2614–2617). The measurement of the penetration of radioactive iron into the grain boundaries of α-iron enables the activation energy of intergranular autodiffusion to be calculated

by the application of Fisher's law, a value of 45 kcal/g atoms being obtained.—L. D. H.

The Mechanism of the Carbon Diffusion Peak in F.C.C. Iron–Nickel Alloys. Wu Tzu-Liang and Wang Chi-Min. (*Acta Physica Sinica*, 1958, **14** (4), 354–368). A peak in internal friction in face-centred cubic Fe–Ni alloys, which at 1·4 cycles/sec is at about 500° K is attributed to preferential rotation of the axes of carbon pairs formed by interaction of substitutional and interstitial carbon atoms. A formula is derived from this mechanism giving quantitative agreement with measured values. Other associated phenomena are described and interpreted.

Diffusion of Sulphur in Liquid Iron. I, II. Diffusion in Liquid Iron Saturated with Carbon. Y. Kawai. (*Nippon Kinzoku*, 1956, **20**, Sept., 514–517; 517–520). [In Japanese]. I. The diffusion coeff. of sulphur in liquid iron has been measured in the range 1560–1670° C. It and the activation energy are nearly the same as for C, Co, and P in iron. The activation energy is about one-tenth of the heat of vaporization. (12 references). II. The diffusion coeff. in liquid iron saturated with carbon has been measured in the range 1390–1560° C using a tracer technique. Values are lower than for carbon-free iron.—K. E. J.

Radioisotopes in Scientific Research. R. C. Extermann (Editor). (*Proceedings* 1st *U.N.E.S.C.O. Internat. Conference*, 1957, *Paris*, 1958). **High-Intensity Cobalt-60 Gamma-Ray Source for Studies in Radiation Chemistry.** A. Kh. Brager, V. A. Belynsky, V. L. Karpov, S. D. Prokudin and V. B. Osipov. (**I**, 122–138). A dose rate up to 1000 r/sec in a vol. of 400 ml or 100 r/sec. in 100 l can be provided. **The Design and Construction of Large Gamma Irradiation Facilities.** G. S. Murray, R. Roberts and D. Dove. (139–150). Shielding design is discussed. **An Investigation of Electric Transport in Solid Solutions of Metals Using Radioactive Isotopes.** I. N. Frantsevich, D. F. Kalinovich, I. I. Kovenskii and B. B. Perkovskii (194–211). Studies with ^{14}C, ^{59}Fe, ^{51}Cr, ^{99}Mo and ^{185}W are described and discussed on the donor-acceptor mechanism. The effects on the strength of alloys to be expected from these elements are also indicated. **Study of Grain Boundary Diffusion in Metals.** V. T. Borisov, V. M. Golikov, B. Y. Lyubov and G. V. Shcherbedinskii (212–231). A new method based on kinetic behaviour is described and applied to the Fe–Si system. Quantitative data can be obtained from autoradiographic measurements. **Effect of Metal Composition and Structure on Grain Boundary Diffusion.** S. Z. Bokstein, S. T. Kishkin and L. M. Moroz (232–248). Experiments on Fe, Ni, Co, Ti, Cr, Cu, Zn, Sn, C and Ni alloys are described and it is shown that there is preferential diffusion along grain boundaries, the influence of the boundaries decreasing as temperature increases. Similar effects are observed in heterodiffusion both in substitution and in interstitial solvents. Small additions of various elements such as B greatly change diffusion rates. The rate of intercrystallite diffusion increases with grain size and rate along grain boundaries depends on degree of ageing as phase precipitation retards diffusion along boundaries. The accelerating effect of stress and deformation is confirmed. **Investigation into Carbon Atom Mobility and Atomic Interaction.** P. L. Gruzin, Y. F. Babikova, Y. A. Polikarpov and G. B. Fedorov (249–270). A study of the state of atoms in solid solutions is made. Diffusion of ^{14}C in ferrite and Ni was measured and it is shown that the α–γ change is associated with acceleration of carbon diffusion. The rate is not changed by alloying with Si, Ni, Cr or Mo. Diffusion in Ni is similar. In Fe–Ni 25% alloy the structural factor has no marked effect. Carbon transfer in γ–Fe under the action of an electric field is indicated. The carbon is in a cationic state in Fe and Ni and the charges are computed for Fe, Ni and some alloys and are shown to change by 1 or 2 units depending on alloy composition. **Application of Radioactive Isotopes in Solving Diffusion Problems in Metal Theory.** A. A. Zhukhovitskii, M. E. Yanitskaya and A. D. Sotskov (279–301). A rapid "printing" method and "thin layer" and "thick layer" methods are described. Studies are made on Ag–Cu and Ag–Sn systems and a theory of diffusion is developed for a medium of irregular mobility. **Study of the Descent of the Charge in the Blast Furnace.** A. Kohn. [In French]. (302–325). Studies in two furnaces of 4·8 and 5·4 m. hearth diameter were made using ^{198}Au and ^{140}La (as oxide), the former going into the metal and the latter into the slag. In some cases small iron capsules were inserted, in others ore and coke were impregnated, or the tracers could be inserted in graphite lumps. The observations were made with a scintillation counter. Slag was generally quiescent, but internal currents were observed in the iron. The descent of the ore transformed into Fe and slag took 4–5 h but the effect of an increase in the proportion of coke took 8 h to appear. The fusion zone is located slightly above the bosch. **The Use of Radioactive Tracers in the Study of Passive Films on Metals.** D. M. Brasher, C. P. De, A. H. Kingsbury and A. D. Mercer (326–342). Studies with chromate labelled with ^{51}Cr are described, the method of preparation being given. Film growth in air and in solution is shown to be logarithmic. The measurements were made on mild steel. An adsorbed film is formed immediately on immersion and growth then proceeds, the rate-controlling process being most probably electron transfer through the film (43 refs.). **A Radioisotope Study of the Effect of Surface Conditions during Wear of Tungsten Carbide.** J. Golden and G. W. Rowe (343–361). A method producing long spiral tracks on a flat disc with neutron-activated carbide is described. The chemical and mechanical state of the surface regulates the amount of wear. **Source of Non-Metallic Inclusions in Steel Ingots.** T. Saito and R. Shimanuki (362–374). Lime containing ^{45}Ca, and ZrO_2 containing ^{95}Zr were added to the pouring refractories. Mild steel, melted in a 150kVA Héroult furnace was tapped into a tagged ladle and a ~90 kg ingot obtained. All non-metallics in ingot, scum, slag etc. were collected, weighed and counted. When nozzle, stopper and fire clay mortar were tagged and the metal poured at 1550° C, 70·07 g of the labelled parts were eroded, 6·04% being transported into the ingot mould, 52·3% floated as scum and 47·7% passed into the ingot. The proportion of labelled to total inclusions in the ingot was 2·86%. Where all refractories of the ladle were tagged, inclusions of refractory origin amounted to 8·47% of the total. Increase of temperature increased erosion with larger proportions floating as scum. **On the Structure and Wear Resistance of Case-Hardened Steel.** L. S. Palatnik, I. M. Lyubarskii and A. P. Lyubchenko. (375–387). Wear-resistance is referred to fine-structure in the most general sense. Besides carbon diffusion in the case-hardening process there is shown to be a back-diffusion of metal atoms to the surface giving an increased vacancy concentration in the crystal lattice. The case-hardened layer of 18 KNVA steel was shown to contain two relatively low-alloy carbides, $(Fe, Cr, W)_3C$ formed on hardening and $(Fe, Cr, W)_{23}C_6$ formed on cooling. Rate of cooling greatly affects fine structure. Rapid cooling produces a wear-resistant structure containing up to 90% residual austenite the lattice of which undergoes comparatively uniform microdeformation with practically no breakage into mosaic blocks. Slow cooling leads to considerable break-up in the comparatively less alloyed austenite and to non-uniform micro-deformation of the γ-lattice. Ordinary methods of heat-treatment cannot correct this breakdown. The structure also forms after a long period of wear of a fine austenite structure. The mechanism of formation of the wear-resistant structure is examined. **An Assessment Trial of Quality of Refractory Materials Used in a Casting Pit and the Distribution of Non-Metallic Inclusions in Steel by Means of Radioactive Tracers.** Z. Bojarski, W. Orzeszko, S. Pawlowski, R. Wusatowski and Z. Ziolowski (388–409). Activated Fe_2O_3 was introduced into casting-pit refractories in fireclay. Ingots and blooms were examined by autoradiographic and counting methods after casting from bricks of refractoriness 1510°, 1690° and 1750° C. It was found that independent of the kind of refractory used in mould and hot-top, the inclusions were found mainly in the body of the ingot. Runner bricks of lowest refractoriness gave the most uniform distribution and the lowest mean radiation intensity. The bricks of highest refractoriness gave the poorest results. The pattern of distribution shows a paraboloid in the head with a shape similar to that of solidification isotherms. In the butt another shorter paraboloid with its vertex upwards was observed. Fractures of blooms showed that inclusions are mostly distributed in a zone up to 7 mm below the surface, the depth increasing towards the top of the ingot. statistical control of deep-drawn products confirms the findings. **Measurement of the Relative Mobility of Cations in Mixtures of Oxide Melts.** V. I. Malkin and L. A. Shvartsman (539–548). Transference numbers of ions in mixtures resembling molten slags were measured. **Thermodynamic Studies of Metallurgical Reactions.** L. A. Shvartsman (609–625). Distribution equilibria of elements between slags and molten iron and determination of their thermodynamic activities have been examined. The elements P, S, Cr, W and Mo were transferred from iron to slags and the thermodynamic functions determined. Partial pressures of the vapours of refractory substances and components of melts were also measured and the properties of solutions of S, P, Cr and Si in iron. A simple method was developed and used for the measurement of the activity of S in cast iron. **Microdetermination of Carbon in Iron Irradiated with Protons.** J. J. Point. (**II**, 180–189). [In French]. The reaction $^{12}C(p,\gamma)^{13}N$ was studied and the effects of impurities were examined. The method is highly specific. **Study of Niobium and Tantalum Complexes for Solvent-Extraction Separations.** E. Bruninx and J. W. Irvine, jun. (**II**, 232–242). Suitable solvents are given such as nitrobenzene, amyl acetate and bis–2–chloroethyl ether with 5:7–dichloro-8-hydroxyquinoline, also systems for chloride solutions. **Electron-Exchange Reactions of Fe(II)–Fe(III) and Co(II)–Co(III) Complexes.** F. S. Dainton, G. S. Laurence, W. Schneider, D. R. Stranks and M. S. Vaidya (305–325).

The Significance of the $\Delta\alpha$ Effect in Iron–Nickel Alloys. G. Pupke and H.-J. Bunge. (*Z. Metallkunde*, 1958, **49**, Dec., 626–629). The significance of the $\Delta\alpha$ effect (the difference in the thermal expansion coefficient α of Fe–Ni Invar alloys after cold rolling, parallel and perpendicular to the direction of rolling) is examined in the light of measurements of the relation of α to the angle between the direction of rolling and the [100] direction. The explanation given is based on the short range ordering of Ni and Fe atoms.

The Specific Heats of Iron and Nickel. G. Valentiner. (*Arch. Eisenhütt.*, 1958, **29**, Nov., 685–688). Experimentally obtained values for the true specific heats of pure iron and pure nickel have been checked against a theoretically derived curve for the temperature range from 0° C to the Curie point.—L. J. L.

High-Temperature Metallurgy Today. L. P. Jahnke and R. G. Frank. (*Met. Prog.*, 1958, **74**, Dec., 86–91). Alloys of improved elevated-temperature strength and other properties belong to groups Fe–Ni, Ni- and Co-base alloys. The addition of Ni to iron alloys allowed the development of austenitic precipitation-hardening alloys ranging from A-286, containing ~25%Ni, to alloys such as René 41 with about 55%Ni. The latter is strengthened by a dispersed second phase consisting of a solid solution of Ni_3Al and Ni_3Ti. The mechanism of strengthening is described.—T. G.

Method for Reduction of High Temperature Data in Terms of a Theory of Deformation, and Addendum. K. F. A. Walles. (*TIDU* 5700, List 970, pp. 51). Procedures for the analysis of creep curves, creep rupture data

and hot fatigue data including rapid graphical methods. Extensive sets of data can be analysed in a very short time and detailed studies for a range of materials are made practicable.

Microvariations in the Deformation of Metals during High-Temperature Heating. M. G. Lozinskii, M. B. Guterman and E. I. Antipova. (*Metall. Obra. Met.*, 1958, (6), 6–9). Direct observation of sections at temperatures up to 1100° C were made under tension in vacuo. Diamond pyramid indentations were made at spacings of 0·05–0·1 mm. The changes in the lengths of the diagonals were measured and the kinetics of deformation are discussed.

Nickel Steels for Low Temperature Service. E. T. Gill. (*Met. Ital.*, 1958, **50**, Dec., 522–528). A review is given of work on low-temperature steels and the reasons for the growing interest in these steels are discussed. The effects of low temperature on the mechanical characteristics of steels are studied as well as the effects of individual alloying elements on their behaviour. Properties imparted by heat treatment and mechanical working are also studied with particular reference to steels containing 3·5% and 9%Ni. The properties of austenitic cast steels are discussed.—M. D. J. B.

Investigations into the Electrolytic Transfer of Carbon, Chromium, and Nickel in Austenitic Chromium–Nickel Steel. F. Erdmann-Jesnitzer and P. Hammer. (*Arch. Eisenhütt.*, 1958, **29**, Nov., 699–707). Results are reported of experiments on the transfer by electrolysis of C, Cr and Ni in Cr–Ni steel wire in the solid phase. The migration of carbon in austenitic Cr–Ni steel has been recorded in polished sections and by microhardness determinations, that of Cr and Ni has also been demonstrated by spectroanalysis. The experiments failed to demonstrate electrolytic transfer of Cr and Ni in γ-Fe.

The Influence of Ultrasonics on the Diffusion Processes of Steels and Alloys at Elevated Temperatures. G. I. Pogodin-Alekseev. (*Metall. Obra. Met.*, 1958, (6), 14–17). Carburization in Armco iron was studied, also in steel 12KhN3A. Ageing and surface saturation were accelerated. The apparatus used was a magnetostriction transducer of up the 5 kVA with a frequency of 21·5 ke/sec. cooled in running water connected by a steel wave-guide to the electric furnace.

Effect of Te and B on Low-Alloy Cast Steel. T. Yamashita. (*Tetsu to Hagane*, 1958, **44**, Mar., 338–340). The effects of metallic Te and Fe–B (analyses given) on the physical properties, austenitic grain size and non-metallic inclusions, are given for seven Mo–Mn and eleven Cr–Mo–Mn steels.—K. E. J.

An Investigation Into the Effect on the Nitrogen-Liquid Iron Solution Equilibria of Additional Elements. H. Schenck, M. G. Frohberg and H. Graf. (*Arch. Eisenhütt.*, 1958, **29**, Nov., 673–6). The melts were prepared in magnesite crucibles placed in a Tammann furnace at 1550°, 1600°, and 1650° C and a nitrogen pressure of 1 atm. Sb, As, Co, Cu, Ni, O, S, and Sn were found to displace nitrogen from the iron solution and to increase its activity: Mo had the opposite effect.—L. J. L.

Effect of Zirconium on Austenite Grain Size in Iron and Steel. K. Mizukawa. (*Tetsu to Hagane*, 1958, **44**, Mar., 426–428). Details are given of the variation of austenitic grain size with zirconium content of iron melted both in vacuum and under nitrogen, and with heating temp. for various zirconium contents.

Effect of V on 2%C–12%Cr Die Steel (SDK1). Y. Matsunaga. (*Tetsu to Hagane*, 1958, **44**, Mar., 409–411). Tests were made on plain SDK1 steel (analysis given) and the same containing 0·54 and 1·05%V. Results are given for hardness and temperature behaviour, and the effect of tempering temp. on length-deformation ratio and on toughness.

Effect of Various Elements on the Properties of High-Nitrogen 19 Cr 8 Ni Valve Steel. M. Kitahara. (*Tetsu to Hagane*, 1958, **44**, Mar., 437–439). The elements studied are C, Ni, Cu and others. Details are given of the mechanical properties at room temp. and high temp. (up to 750° C).—K. E. J.

The Influence of Various Elements on the Properties of 20%Cr–9%Ni Heat-Resisting Steel. K. Kusaka. (*Tetsu to Hagane*, 1958, **44**, Mar., 433–435). The elements studied are C, Ni, V, Ti and others. Changes of hardness in ageing are described and the effects of alloying elements on rupture strength are shown.—K. E. J.

Influence of Various Elements on Properties of S-816 Alloy. K. Kusaka. (*Tetsu to Hagane*, 1958, **44**, Mar., 435–437). The elements studied are C, Si, Co and others, as well as La + Ce (Lan Cer Amp) additions. Changes are described, and the effects of alloying elements on rupture strength are shown.—K. E. J.

Mechanical Properties of 18–8 Type Stainless Steel Wire. I. Effect of Ni Content. T. Watanabe and J. Saga. (*Nippon Kinzoku*, 1957, **21**, Oct., 583–587). For two steel wires (analyses given) results are given for phase transformations with varying degrees of reduction, variations of physical properties with rate of drawing, hardening by annealing after cold working, and effects of annealing on physical properties. (12 references). **II. Effect of C Content.** (602–606). Empirical equations are given for relationships between the hardness, tensile strength and yield point of the cold-drawn and annealed and drawn wire. For cold-drawn wires, the proportional limit is low and independent of reduction of area (20–90%) and carbon content (0·03–0·08%); it is increased by annealing after drawing. For stainless steel wire, cold-drawn and annealed, the proportional limit is independent of the same parameters.—K. E. J.

The Conception of Oligo-elements, Particularly in Metallurgy. A. Portevin. (*Génie Civil*, 1959, **136**, Jan. 1, 9–13). A general account of trace elements (the "essential trace elements" of physiology for example), which the author endeavours to extend to those producing effects in very small quantities in metals and alloys. Al, B, N, O, P, S and Cu are regarded as oligo-elements in steel. Crystallographic and similar effects are referred to.

High Strength Low Alloy Steel. (*A.I.S.I. Steel Prod. Manual*, 1958, Dec., pp. 57).

A Study on Austenitic Heat-Resisting Steels. I. R. Nakagawa. (*Tetsu to Hagane*, 1958, **44**, Mar., 442–443). Particulars are given of hardness changes in ageing treatments, and of creep-rupture properties as related to temp. of solution treatment.—K. E. J.

Weldable Constructional Steels of the Type St. 52. I. Balsay. (*Koh. Lapok*, 1958, **13**, July, 326–333). In this second part of the paper the author discusses the influence of various alloying elements, as well as the effect of microstructure and material thickness, on the mechanical properties and weldability of constructional steels. Bainite is especially advantageous for increasing the rate of change of yield point with tensile strength. The price of alloying elements is also considered. The author asserts that the Vollmacher formula: U.T.S. kg.p.sq.mm. = 25 + 100 1% + 10(Si% − 0·20) + 15.(Un% − 0·60) + 100.(P% − 0·020) + D, can be satisfactorily used for getting the tensile strength of these steels. He also gives some new data for the constant D; this factor shows the effect of thickness. The author supplements the above formula by the term: 20(Cu% − 0·20). For a high strength weldable steel of U.T.S.33–40 t/in² and Y.P.21 t/in², the suggested maximum limits of chemical composition are: C 0·20%, Mn 1·3%, Si 0·55%, Cr 0·15%, lu 0·45%, S 0·04%; P 0·04%.

Chromium–Aluminium Steels. Properties and Applications. E. Herzog. (*Corros. et Anticorros.*, 1958, **6**, April, 117–126). The author gives an historical survey of corrosion testing of steels in aqueous media. He then discusses the main characteristics of Cr–Al steels, particularly from the point of view of corrosion resistance in nitrate solutions and in H_2S.—R. P.

A Study on Titanium Steel. H. Hirano. (*Tetsu to Hagane*, 1958, **44**, Mar., 407–409).

DTD 166-Type Austenitic Chromium–Nickel Sheet Steel: A Summary of Properties. (*TIDU*6005, pp. 22, List. 971). A stabilized 18 Cr 7 Ni steel is discussed, giving mechanical properties as received, after "modulus recovery," heat-treatment, and also describing welding and forming properties.

Study of Leaded Free-cutting Steels. Study of Characteristics of Leaded Case-hardening Alloy Steel. T. Araki. (*Tetsu to Hagane*, 1958, **44**, Mar., 368–370). Comparisons are made between SCM 22 steel with and without added lead (0·11%), in respect of mechanical properties, Charpy impact values for cemented and non-cemented specimens, and service behaviour.—K. E. J.

Heat-Resisting Steels and Alloys. (*Aciers Fins Spéc.*, 1958, Dec., 24–28). Various Cr steels are briefly reviewed with their creep properties and refractoriness.

[Survey of Work on] Ball-Bearing Steels. II. (*Tetsu to Hagane*, 1958, **44**, Apr., 493–504). A review, with 87 references.—K. E. J.

High Speed Steel. Development of a New Type with 5%W and 5%V. P. Kövesi. (*Iron Steel*, 1958, **31**, Nov., 529–532). Following the modern tendency to reduce W content in high-speed steels, a 5%W, 5%V steel has been developed by B.I.S.R.A. The hardness properties of the steel seem to suggest that it could replace the usual 12–18 W steels for many purposes.

METALLOGRAPHY

Investigation of Metal Structures at High and Low Temperatures. P. Ryš, L. Bezděk, K. Čiha, D. Růžička and J. Škarek. (*Acta Technica*, 1958, **3**, (1), 58–83; (2), 85–120). The underlying principles of high and low temperature microscopy are outlined, and the equipment available reviewed, with special reference to the apparatus developed by Bezděk and Růžička. Structural investigations carried out with the equipment are described. II. This section gives the results of the steel structural investigations using high and low-temperature microscopy. Particular reference is made to the use of thermal etching of steel and cast iron specimens. (37 references).

Ores and Their Examination under the Polarizing Microscope. H. W. Walther. (*Echo Mines*, 1959, Jan., 35–38). An account of polarization microscopy as applied to opaque specimens for the identification of constitutents is given.

Rapid Method of Preparation of Surfaces for Metallographic Examination by Local Electrolytic Polishing. P. A. Jacquet. (**Note Technique O.N.E.R.A.*, No. 40, 1957). Tampon polishing for surface preparation for replica casting is described. Numerous examples are given and the microstructures shown; one stainless steel section is included.

Electrolytic Polishing of Carbon and Low Alloy Steels in Molten Salts. The Austenitic Structure and Grain. Z. Wojcik. (*Mét. Corr. Ind.*, 1958, **33**, Feb., 53–70). The method enables the austenitic structure to be confirmed in steels in which it usually exists only at high temperatures. Two methods are described and results discussed. Grain growth and related phenomena as well as the internal structure of austenite are dealt with. (40 references).—R. P.

The Influence of the Etching Process on Structure Reproduction in the Electron Micrograph. A. Schrader. (*Arch. Eisenh.* 1958, **29**, Dec., 793–797). Accelerated removal of ferrite or austenite takes place in the neighbourhood of carbide inclusions in the early stages of etching with HNO_3 or picric acid, although this accelerated action disappears later in the etching process. The effects of this selective action on the reproducibility of the structure as shown in relief and extraction replicas are respectively discussed.

A New Oxidising Method for Revealing Austenitic Grains. Y. Imai and H. Hirotani. (*Tetsu to Hagane*, 1958, **44**, Apr., 480–482). When the specimen is exposed to air at high temp. for a few seconds, the grain boundary is preferentially oxidized, and on dipping into molten borax the oxide dissolves away and

leaves a groove. Tests on carbon and special steels show the simplicity and reliability of the technique.—K. E. J.

Electropolishing and Electrolytic Etching of Microsections of Iron-Copper Powder Compacts. O. K. Teodorovich and E. T. Kachkovskaya. (*Zavods. Lab.*, 1958, **24**, (1), 57–60). Apparatus is described and operation using H_3PO_4–CrO_3, and suitable current densities for one and two-phase systems are given. The structures revealed are shown.

The Preparation of Shadowed Plastic Replicas. S. T. Ross and D. M. Teague. (*Proc. A.S.T.M.*, 1957, **57**, 527–535). Cr shadowing is used.

The Two-Stage Preshadowed Carbon Positive Replica Method for Electron Metallography. R. L. Scott and A. M. Turkalo. (*Proc. A.S.T.M.*, 1957, **57**, 536–553). Methods for surfaces of different degrees of smoothness are given.

Non-Destructive Techniques for Macro- and Micrographic Surface Examination of Metallic Specimens (Electrolytic Local Polishing and Replica Technique). P. A. Jacquet. (*Proc. A.S.T.M.*, 1957, **57**, 1290–1303). The Replic lacquer process is described and recommended.

Improvements and New Applications of the Technique of Non-Destructive Metallographic Examination. P.-A. Jacquet. (*Rev. Mét.*, 1958, **55**, June, 531–553). A technique previously described (*ibid.* 1957, **54**, 107) in which a combination of local electrolytic polishing and the preparation of replicas was used for non-destructive metallographic examination has been improved, and its range of application increased. Details of these improvements and new applications are given.

Electron Microstructure of Bainite, Pearlite, and Tempered Martensite in AISI 4140 Steel. (*Proc. A.S.T.M.*, 1957, **57**, 475–520). A large series of excellent micrographs is shown. The preparation of the specimens is described. Replicas were made for the electron microscope.

Evaluation of the Quality of Boron Steels, in Particular by a Micrographic Method. P.-A. Jacquet and R. Capelle. (*Rev. Mét.*, 1957, **54**, Nov., 855–866). As ordinary micrographic reagents reveal no differences between the micro-constituents of hardened steels of the same basic composition, with or without boron addition, a technique suitable for the purpose was sought, and the paper describes a successful method based on the reagents proposed by Béchet and Beaujard (1955, **52**, 830).

X-Ray Crystallographic Study of Tempered Martensitic Carbides Prepared by Quenching Pure Iron-Carbon Steels. F. Marion and R. Faivre. (*Rev. Mét.*, 1958, **55**, May, 459–469). Results show that the carbides formed by tempering may be regarded as a continuous series of non-stoichiometric compounds. Their structure is derived from that of cementite by the subtraction of carbon atoms and is given as $Fe_3(C_{1-y}\ \ )_{1y}$ where ( ) signifies a carbon vacancy and y lies between 0·29 and 0·00.—A. G.

Study of Iron Carbides by Electron Diffraction. I. S. Oketani and S. Nagakura. (*Nippon Kinzoku*, 1956, **20**, Aug., 460–465). The 'iron powder' technique is described for producing hexagonal ϵ-carbide, Hagg χ-carbide, and θ-carbide (cementite) by passing CO or $(CO + H_2)$ atmospheres over vacuum-deposited iron films covered with reduced iron powder. Various parameters of the carbides are described, and the allotropic $\epsilon \rightarrow \chi \rightarrow \theta$ transition is discussed. **II. Phase Transition of the Carbides.** S. Nagakura. (465–468). The transformation $\epsilon \rightarrow \chi \rightarrow \theta$ is irreversible. The transition $\epsilon \rightarrow \chi$ takes place at 380–400° C, and that of $\chi \rightarrow \theta$ at approx. 550° C. The θ carbide changes to iron and carbon with prolonged heating above 550° C. The 380° C Curie point of ϵ-carbide (Hofer et al.) is the $\epsilon \rightarrow \chi$ transition temp.—K. E. J.

Quantitative Metallographic Determination of Alpha Phase in Austenitic Weld Metal. A. D. Kuznetsova-Sadovnikova. (*Svarochnoe Proizvodstvo*, 1958, Jan., (1), 34–36). An etching process is described for quantitative α-phase studies. To reveal the dendritic weld-metal structure and its junction with parent metal, electrolytic etching in chromic acid is recommended.

Investigations on the Course of Deoxidation on the Formation of Inclusions in Steels. (*Forsch. Wirts. Nordrhein-Westfalen*, No. 49, 1953, pp. 45). Factors in the composition and size of inclusions in steels treated with Mn, Si, and Al are examined.

The Occurrence of a Cubic Nitride in Aluminium-alloyed Steels. F. Wever, W. Koch, C. Ilschner-Gensch, and H. Rohde. (*Forsch. Wirts. Nordrhein-Westfalen*, 1957, No. 409, pp.26). A low-carbon steel with 0·005–0·75% Al nitrided in NH_3 at 600° C and heated in a stream of NH_3 at 1000° for 48 h contained a new nitride including Cr. A steel with 1% Al and 1·3% Cr or 1·2% Cr and 0·19% Mo similarly nitrided also contained the cubic constituent.

Study on Carbides in Iron and Steel by Electrolytic Isolation. V. Effect of Various Elements on Curie Point of Cementite. T. Sato and T. Nishizawa. (*Nippon Kinzoku*, 1956, **20**, June, 340–344). The Curie point of austenite is lowered according to the formula $A_0 = 215 + pM$, in deg C, where M is the concn. of the third element; values of p are given for Co, Ni, Cr, Mo, W, Mn, and V. From the lowering of the Curie point, it is concluded that solubilities in cementite at 700° C are: Mo 1·8%, W 1·3%, V 0·6%, and Ti 0·1%. Si, Al, S, and P slightly lower the Curie point, suggesting some solubility in cementite.

The Metallurgical Control of Slag Inclusions and Carbide Segregations in Bearing Steel. K. Fellcht and R. Barz. (*Neue Hütte*, 1958, **3**, June, 341–350). The effects of operating conditions in the manufacture of roller bearing steels 100 Cr 6 and 100 Cr Mn 6 on the incidence of slag inclusions and carbide segregation were examined. In the case of carbide segregation, rolling mill practice was found to exert the greatest influence. The effects of heat treatment on segregation are discussed.

Contribution to the Study of the Influence of the Process of Manufacture on the Nature and Contents of Non-Metallic Inclusions Present in Steel. S. Dascălu. (*Studii si Cercetări de Metalurgie*, 1958, **3**, (1), 39–52). [In Rumanian]. The physico-chemical factors which influence the type and amount of the non-metallic inclusions present in steel as a result of the process of manufacture have been studied on 25 heats of killed steel made in O.H. furnaces. Speed of decarburization, length of boil, and the amount and order of addition of deoxidants are amongst the factors investigated.

Investigations on the Isolation of Grain Boundary Constituents and Inclusions in Steels by the Thin Section Method. H. Schenck, E. Schmidtmann, and H. Müller. (*Arch. Eisenh.*, 1958, **29**, Aug., 479–484). Experiments are described in which the effect of a decarburizing anneal under moist hydrogen on the isolated constituents of unalloyed iron was investigated, the iron samples containing varying amounts of carbon. It was concluded that the results were falsified due to decarburization of the thin sections before the isolation treatment. Other trials were made, separating the base metal by chlorination or solution in iodine-alcohol. Results were inconclusive, as in no case was a coherent grain boundary network obtained.

The Potentiostat in Metallography. V. Čihal, M. Pražák, and M. Holinka. (*Hutn. Listy*, 1958, **13**, (6), 496–502). Researches on the identification of phases occurring in 18/8 steels by etching electrolytically at various potentials maintained at constant levels by means of a potentiostat are described. Conditions for etching ferrite, austenite, austenite grain boundaries, martensite, and sigma-phase are given, and the results are compared with similar data given by Edeleanu. (*J.I.S.I.*, 1957, **185**, 482–488).—P. F.

Quantitative Study of Dendritic Heterogeneity in Iron Alloys. C. de Beaulieu and J. Philibert. (*Compt. Rend.*, 1958, **246**, June 30, 3615–3618). The variation in composition from dendrite ores to the interdendritic space is determined autoradiographically and by point microanalyses. Heterogeneity increases in the order Mn, Cr, Mo, As.

Contribution to the Study of the Banded Structures in Forged Steel. C. Roques, C. Dubois, and P. Bastien. (*Rev. Mét.*, 1957, **54**, Nov., 821–839). The principal characteristics of banded structures of steel are reviewed, and the influence of P is discussed. Microsegregation appears to play a predominant part, and the results show the need for examining the effect of other impurities and alloying constituents, as well as that of P. Using mainly dilatometric methods, the influence of P on γ-grain size and on transformation temperatures was examined. (15 refs.).

Researches on the Fibre Structure of Alloys and Solid Solutions and its Removal by Strain-Tempering Treatment. T. Sano, J. Satake, and T. Otani. (*Nippon Kinzoku*, 1956, **20**, Aug., 413–417). Results are given for 0·4% C and 0·8% C steels. Cold-rolled specimens show heterogeneous microscopic structures, accompanying fibre structures, which cause defects. Strain-tempering can remove fibre structures and produce homogenizing; this leads to an improvement in mechanical properties beyond what can be attributed to the heat-treatment.—K. E. J.

Formation of the Goss Texture in Silicon Iron. K. Detert. (*Metall*, 1958, **12**, Sept., 817–821). The author reviews published work on the processes that contribute to the formation of the Goss texture in silicon iron. Cold working forms a matrix in which grains having Goss orientation grow preferentially. The role of alloying additions in promoting selective growth of grains with Goss orientation by secondary recrystallization is mentioned.

Structural Modifications of a Stainless 10% Nickel Steel Deformed between − 200° and + 800° C. B. Jaoul. (*Rev. Nickel*, 1957, **23**, (4), 91–97). The properties and structure of austenitic stainless steel containing 10% Ni both below and above room temperatures are examined.

Thermodynamics of Iron-Carbon Melts. E. T. Turkdogan and C. R. Masson. (*Acta Met.*, 1958, **6**, July, 519–520). A letter. The results obtained by the authors on the activity of C in Fe–C alloys (1956, **4**, 396–406) have been criticised by Cordier (1957, **5**, 336–337) on the grounds that certain secondary reactions would lead to experimental concentrations of CH_4 which were too high. It is pointed out that water-vapour pressure was maintained in the experiments at a level sufficient to suppress the formation of excess CH_4, with the possible exception of those carried out at 1500° C. Relevant data are discussed.

Studies of the Stringer-Like Structures in Plain and Alloy Structural Steels. E. Plockinge and A. Randak. (*Stahl Eisen*, 1958, **78**, July 24, 1041–1058). The authors describe experiments on the causes of structural variations in plain and alloy steels in the as-cast condition and after hot working. Theoretical considerations on the crystallization involving segregation caused by diffusion rates and phase separation are included. The difference in the phenomena observed in plain and alloy steels is explained and the particular role played by carbon elucidated. The effect of hot-working on carbon separation is discussed and the influence of the various alloying elements described.

The Effect of Nickel, Copper, and Manganese on the Spheroidisation of Cementite in Ball-Bearing Steels. R. Štefec and F. Labonek. (*Hutn. Listy*, 1958, **13**, (5), 407–412). A study of the effect of the variation of the content of alloying elements in ball-bearing steels (1·04% C) showed that (1) irrespective of the method of annealing used, nickel and copper up to 0·64 and 0·65% respectively are equivalent and their effect additive, after annealing. (2) With an increasing amount of Cu + Ni up to 1·14% total, the Ac and Ar points are continuously lowered, and the hardness increases in the furnace cooled and normalized states if the manganese content lies within 0·21–0·44%. (3) Up to 1·14% Ni + Cu an increase in the joint nickel and copper content leads to a slight gradual increase in the amount of lamellar pearlite after annealing, provided this takes place below Ac_3. (4) A low manganese content is even less favourable than increasing the joint Ni + Cu content up to

1·14% in its effect of opposing the complete spheroidization of the cementite. (5) If the manganese content is around 0·04%, acceptable structures are obtained only if the Ni + Cu content lies below 0·9%, and if a two-stage sub-critical annealing process is used. The various annealing processes used and their respective advantages and disadvantages are discussed in detail.—P. F.

Morphology of the Brittle Phase Formed in Resistance-Welding of Low-Carbon Steels. D. Hrivňák and I. Hrivňák. (*Hutn. Listy*, 1958, **13**, (6), 512–517). [In Slovak]. An electron-micrographic study disclosed two brittle phases, one apparently amorphous, the other probably martensitic. The micrographs, and the possible nature of the phases are discussed; the observations do not, however, permit definite identification without additional studies.—P. F.

Sigma Phase in Austenitic EI 448 Steel. E. I. Uryupina and A. F. Likina. (*Metallov. Obra. Met.*, 1958, (6), 37–41). The steel contains 0·1%C, 1·09%Mn, 0·73%Si, 16·58%Cr, 11·9%Ni, 0·62%Ti, and 1·75%Mo, quenched from 1200° C and aged 10–6000 h at 575° or 800° C. Sigma phase was isolated electrolytically and the residues examined by X-rays. σ-phase was also detected by etching with various reagents and the specimens were tested for resistance to intergranular corrosion in $CuSO_4$ solution with subsequent bending. It is formed after relatively short periods and increases with ageing time. It is not detected by magnetic analysis even at 800° C and must be formed directly from austenite. It decreases impact strength and reduction of area values but does not shorten time to rupture nor lower creep.

Electron Microscope Investigation of the Structure of 18 9 CrNiTi Steel After Various Heat Treatments. E. I. Kvashnina. (*Metall. Obrabotka Met.*, 1957, (5), 35–38). The preparation of specimens for electron microscope examination to study the structural changes in 18·9 CrNiTi steel during heat treatment is described. Examination of the quenched steel showed that the austenite grains had a block structure with varying orientation of the blocks in each grain and at its boundaries. In the structure of steel quenched from 1100–1300° C, titanium carbide was present, but the amount diminished as the quenching temperature was raised. The author was not able to ascertain the nature of the acicular phase although metallographic analysis showed that the marked increase in impact strength observed with high quenching temperatures (above 1150° C) is associated with the solution of particles of the acicular phase and also of particles located at the grain boundaries. Electron microscope examination of the steel after quenching and ageing revealed an acicular phase in the structure which had not been observed with the optical microscope. With ageing at 575° C, the electron microscope reveals this phase only after holding for about 1000 h. This phase somewhat increases the tensile properties and lowers the ductile properties. At 800° C, the precipitation of the acicular phase increases in intensity. Ageing even for only 10 h causes precipitation of the acicular phase in a greater amount than is produced with ageing for 1000 h at 575° C.

Effect of Retained Austenite on Properties of Steel. E. I. Malinkina. (*Metall. Obrabotka Met.*, 1957, (4), 44–47). A previous article showed that the effect of retained austenite in low, medium, and high-C steels varied. An increase in retained austenite in low-C steels lowered the tensile strength but had the opposite effect in medium and high-C steels so that the tensile strength of the latter with an austenitic structure is higher than that of the same steel having a martensitic structure. The authors of this former article stated that the strength of high-C steel with an austenitic structure was more than twice as great as that of the same steel with a martensitic structure at room temperature. This previous article, it is therefore maintained, gives rise to some contradictions which are discussed. It is considered that better results regarding the effect of austenite and martensite on the strength of steel are determined for a given alloy composition and grain size. The present article does not confirm the previous hypothesis of Russian workers regarding variations in tensile strength in relation to the martensite/austenite ratio in medium and high-carbon steels.—R. S.

Influence of Induction-Heating Parameters on Austenite Grain Size in Nickel Steel. I. N. Kidin. (*Metallov. Obrabotka Met.*, 1957, (9), 36–42). After discussing induction heating in relation to phase transformations and alloying elements, the author gives results of observations of grain size in a series of induction heated steels with 0·2–1·1%C, 0·41–0·64% Mn, 0·16–0·33%Si, 0·013–0·023%P, 0·012–0·027%S, and about 1, 2·5, 5, and 10%Ni. The influence of the induction heating factors on the austenite grain sizes was found to be the same for all cases. With constant heating rate increasing heating temperature leads to grain-size increase; with constant temperature, increased heating rate leads to smaller grains. Grain growth was more rapid in nickel- than in chromium-steels under similar conditions.

Observations of Austenite Structure of Carbon Steels Containing Different Amounts of Aluminium by the High Temperature Metal Microscope. S. Hasebe. (*Sumi. Met.*, 1957, **9**, Oct., 207–215). [In Japanese]. Results are given showing heat-etching austenite structures of high-and low-carbon steels containing varying Al contents at 900°, 1000°, and 1100° C, and the effect of this structure on growth processes. The heat-etching structure has a smaller grain size than the cementite and ferrite nets, but the heat-etching surface has some characteristics of grain boundaries.

Relation of the Orientation of an Unstable Phase in Steel and the Phase Resulting from Its Plastic Deformation. P. Bastien and R. Margerand. (*Génie Civil*, 1958, **135**, Sept. 15, 375–376). In 18–8 steels, plastic deformation converts some γ-phase to α-phase. Micrographic and X-ray studies are reported on 18–8 and 18–4 manganese steels compressed at room temperature and at 300–370° C. The process is similar to bainite formation, a large number of very small crystals being formed.

Domain Wall Orientations in Silicon–Iron Crystals. C. D. Graham jun. and P. W. Neurath. (*J. Appl. Phys.*, 1957, **28**, Aug., 888–891).

On the Crystal Structure of the Intermediate Phase ω in Titanium–Iron Alloy. H. Yoshida. (*Nippon Kinzoku*, 1956, **20**, May, 292–294). Single-crystal X-ray examinations were made on Ti–6% Fe alloy. The ω phase has a complex body-centred cubic lattice, the parameter being $a_\omega = 9·76$Å. The space group is Im3m. The orientation relationships between β and ω phases are $(100)_\beta // (100)_\omega$, $[010]_\beta // [010]_\omega$. The phase may be an intermetallic compound.

The Formation of ε-Carbide by the Tempering of Low-Carbon Martensite. S. Modin. (*Jernkonts. Ann.*, 1958, **142**, (4), 209–211). Investigations are described into the formation of ε-carbide in the tempering of a steel containing 0·18%C at temperatures of 200°, 300°, and 400° C.—L. D. H.

The Form of Precipitation of Cementite in Ferrite. W. Pitsch and A. Schrader. (*Arch. Eisenh.*, 1958, **29**, Aug., 485–488). Orientation determination on cementite particles precipitated in massive steel samples (in contrast with experiments on very thin sections previously described in the literature) showed the existence of the relationship: $(211)_\alpha \| (001)_{cem.}$; $[011]_\alpha \| [100]_{cem.}$; $[111]_\alpha \| [010]_{cem.}$

The Direct Observation of Phase Transformations in Metals. R. Mitsche, F. Gabler, and W. Wurz. (*Berg. Hütten. Monatsh.*, 1958, **103**, June, 105–109). After a brief review of various techniques employed for direct observation of phase transformations, the application of a new method developed by UNITRON to the observation of austenite growth and transformation curves in a Cr–Ni–Mo steel is described.—L. D. H.

The Influence of Bismuth on the Graphitization of Cast Iron During Its Solidification. Tsai Hsiao-Chu and Lui Chi-Chiung. (*Scientia Sinica*, 1958, **7**, Oct., 1061–1078). [In English]. Only a small quantity of Bi can be absorbed when added in the ladle, the residual content in these experiments was never above 0·018%, however a very small amount (0·009% for an iron with 2·63%C and 1·48%Si) will change grey iron to white. This effect can prevent mottling in heavier malleable castings. Plotting carbon equivalent (C + ⅓Si and C + 2·85/log Si) against Bi gives 2 diagrams. Unless the equivalent is lower than a critical value depending on casting thickness and so on cooling rate Bi cannot convert grey iron to white. C + ⅓Si > 3·64 is the critical carbon equivalent of mottled iron. Bi stabilizes carbide during solidification but during the eutectoid transformation it probably acts as a weak graphitizer.

Mechanism of the Effect of Low Temperature Treatment of White Cast Iron on the Number of Graphitization Nuclei with Subsequent Annealing. G. I. Ivantsov. (*Metall. Obrabotka Met.*, 1957, (4), 9–16). The localization of graphite nuclei in the structure of white cast iron and the effect of low temperature treatment on graphite nucleation in 'as cast' and 'as quenched' white iron is discussed. Nucleation of graphite when holding above and below eutectoid temperatures after rapid heating is reviewed.—R. S.

Study on Graphitic Steel. II. Effect of W, Mo, Cr, and Ni on Graphitization of Graphitic Steel. T. Sato and S. Toya. (*Nippon Kinzoku*, 1956, **20**, May, 239–243). Studies were made on standard steels containing 1·5%C and 1·0–1·5%Si, with other elements added. W, Mo, and Cr improved forgeability, while Ni had a deleterious effect. The graphitization was retarded slightly by W and Mo and strongly by Cr, and accelerated by Ni. The optimum amounts of special elements (added separately) are 2·5%W, 1·5%Mo, 2%Ni, and < 0·3%Cr.—K. E. J.

The Influence of Magnesium on the Eutectoid Transformation Temperature of Nodular Cast Iron. F. Varga and J. Vereskói. (*Kohászati Lapok*, 1958, **13**, Feb.–March, Ontside, 37–41). Tests carried out in Hungary with nodular cast irons containing up to 6%Si show that Mg increases the eutectoid transformation temperature. This increase is 45–50° C for a normal nodular cast iron containing 2–3%Si, but only 35° C for a similar cast iron containing 0·5%Ni.—P. K.

Some Problems in the Formation of the Structure of Carbon Steel. A. N. Alfimov. (*Metallov. Obrabotka Met.*, 1957, (9), 17–18). The author discusses structural transformations in carbon steel with special reference to the austenite transformation. He considers that there is a range where this is martensitic and uses this idea, allowing for the influence of transformation temperature, phase stresses and thermal stresses due to heat-evolution in the transformation, to explain some known effects including increased carbon concentration and quantity of carbides round tempered martensite crystals and crystals formed by isothermal soaking of austenite at intermediate temperatures and the change of carbon concentration in austenite and crystals of the new phase during austenite transformation at intermediate temperature.—S. K.

New Knowledge in the Field of Transformation of Steel. E. Greulich. (*Draht*, 1958, **9**, Apr., 119–131). A summary is presented of comprehensive investigations into the thermal transformation of steel, carried out in the research laboratory of the company Isolation A.G., Mannheim, and based on measurements of the hardness of heat treated specimens. These enabled changes to be detected which take place in a time shorter than those detectable by dilatometry. TTT-diagrams for a range of carbon and alloy steels are shown, to illustrate departures from curves determined dilatometrically, which remove some of the contradictions hitherto present as between straight carbon and alloy steels. Conclusions are drawn about the implications of these findings for heat treatment, notably about the possibility of extending the patenting treatment to alloy steels.—J. G. W.

Transformations in Rapidly Heated Steel. S. Gorczyca and T. Boniszewski. (*Hutnik*, 1957, **24**, Nov., 436–448). [In Polish]. Transformations during heating at different speeds are discussed. The form of the austenite grain derived from different initial crystalline struc-

tures during quick and slow heating processes is discussed. The research on the recrystallization of austenite, carried out by the author, is described and illustrated by numerous photographs and graphs.

Effect of Low Temperature Deformation on Phase Transformations and Properties of a Russian 18/9 CrNiTi Steel. A. P. Gulyaev and I. V. Chernenko. (*Metall. Obrabotka Met.*, 1957, (5), 2–7). 18/8 CrNiTi steel undergoes a γ–α_2 transformation. The amount of martensite which is formed increases with the degree of deformation and diminishing deformation temperature. The most intensive growth in the amount of the magnetic phase is produced with a deformation of about 80% (torsion at — 70° C). A further drop in temperature and increase in deformation have a negligible effect on the increase in martensite.—R. S.

Pearlitic Transformation in Chrome Steel Containing Niobium and Zirconium. D. Ya. Vishnyakov and L. S. Ol'khovoi. (*Metallov. Obrabotka Met.*, 1957, (9), 18–21). Results are presented of investigations of isothermal austenite transformation in two chrome steels containing respectively: 0·35, 0·37%C; 0·3, 0·51%Mn; 0·28, 0·25%Si; 2·15, 2·07%Cr; 0·25, 0%Nb; 0, 0·05%Zr; 0·007, 0·017%S; 0·030, 0·016%P. Preliminary heating temperatures were 1000° and 1300° C. Kinetic curves, transformation diagrams, and microstructures are shown. From these it is concluded that in the isothermal transformation of supercooled austenite in these steels in the pearlite range the form of the pearlite changes into needles when the supercooling extends to below the upper bend of the S-curve. In the upper part of the intermediate range the transformation of austenite into needle-shaped troostite does not go to completion, the remaining austenite later changing into pearlite needles.—S. K.

The Influence of Tungsten on the Kinetic Parameters of Formation of Pro-Eutectoid Ferrite. K. Mazanec and J. Čadek. (*Rev. Mét.*, 1958, **55**, June, 501–512). The influence of W on the rate of nucleation and growth of pro-eutectoid ferrite was studied in two 0·4%C steels containing 0·54 and 1·58%W respectively. Between 675° and 745° C the speed of nucleation was reduced by the presence of W, almost independently of temperature, the speed of growth being diminished substantially below 650° C and hardly altered above 745° C with very pronounced undercooling speed of growth is controlled by the rate of diffusion of carbon in austenite. (21 references).

On the Tempering of Certain As-Quenched Structures of Carbon and Alloy Steels. J. Papier. (*Bol. A.B.M.*, 1958, **14**, July, 363–402). [In Portuguese]. The author reviews the present state of knowledge of the effects of tempering upon martensitic and austenitic–martensitic structures in steel. Relationships between the tempering effects and the mechanical properties are shown. The value that industry can obtain from fundamental research in this field is illustrated by reference to the development of the high-strength steels and the improved heat treatment of high speed steels. (19 references).—P. S.

The Effect of the Annealing Cycle on the Pearlite–Cementite in an Un-alloyed Steel with 0·86%C. H. Modin. (*Neue Hütte*, 1958, **3**, May, 305–306). A study has been made of the changes in the pearlitic structure of an eutectoid carbon steel due to annealing. Thin samples were heated to 1100° C, immediately transferred to a metal bath at 650° C, the austenite being converted into pearlite, and were annealed for varying periods at 650° C (2 sec to 50 hours). The microstructure of the samples was studied under the microscope and the electron microscope.—L. J. L.

The Austenite Transformation in an Arbitrary Cooling Process. V. A. Lomakin. (*Izvest. Akad. Nauk Otdel. Tekn.*, 1958, (2), 20–25). The object of this study was to determine mathematical formulae for the theoretical investigation of the various problems concerning the kinetics of structure transformations, i.e. the course of structure transformation in arbitrary cooling conditions, the tempering of various shapes under various conditions, the determination of the optimum conditions for through-tempering and the distribution of the structure throughout the entire cross-section of the cooled specimen.—L. B.

Contribution to the Study of the Mechanical Properties of Isothermal Decomposition Products of Austenite from Some Engineering Steels. R. Potaszkin and K. Bar-Avi. (*Rev. Mét.*, 1958, **55**, Apr., 345–363). The relationship between the various microstructures found on isothermal decomposition of austenite and mechanical properties has been investigated. Three steels (Ni–Cr, Cr–Mo, and Mn) were studied. The lower bainite in all three was found to be associated with mechanical properties which could be compared with those obtained by quench and temper while upper bainite was distinguished by low values of yield strength, reduction of area, and of impact strength.—B. G. B.

Microstructural Study of the Decomposition of Supercooled Austenite in Magnesium Cast Iron with Spheroidal Graphite. D. Sh. Frolov and A. N. Mirza. (*Metallov. Obrabotka Met.*, 1957, (9), 4–9). The isothermal austenitic transformation has been studied in an iron (3·12%C, 0·55%Mn, 3·5%Si, 0·012%S, 0·10%P, 0·10%Cr, 0·10%Ni, 0·05%Mg) obtained by inoculation with a magnesium–ferrosilicon alloy at 200–700° C. Three transformation ranges were noted: pearlite (over 600° C), intermediate (250–550° C) and martensite. In the first a pearlitic structure is formed in which the cementite coagulates and graphitizes at rates increasing with temperature and time of soaking. In the intermediate range, decomposition starts with the formation of needles whose shape and location depend on the degree of supercooling.—S. K.

Transformation of Cementite Into Austenite and Ferrite in the Graphitization and Decarburization of Cast Iron. K. P. Bunin and S. N. Ivanov. (*Metallov. Obrabotka Met.*, 1957, (10), 2–4). Data are presented on the microscopic transformation of cementite into austenite and ferrite obtained in a study of graphitization and decarburization of hypo-eutectic white iron inoculated with Mg (3·12% C, 0·49%Si, 0·38%Mn, 0·44%P, 0·008%S, and 0·062%Mg). The results show that the cementite coexisting with a solid solution not saturated with carbon is so impoverished in carbon and enriched in iron that nucleation and growth of solid-solution crystals becomes possible in it. Under certain conditions this can occur as well as the growth of solid-solution crystals on the initial cementite–austenite and cementite–ferrite boundaries.

Manganese-Substituted Cementites. P. Lesage-Bourdon and A. Michel. (*Comp. Rend.*, 1958, **246**, May 5, 2 624–2 627). A note. Homogeneous solid solutions of Mn in cementite of the general formula $(Fe_{3-x}Mn_x)C$ were obtained by the diffusion of C into ferro-manganese at high temperatures, and a thermo-magnetic analysis was carried out.

Strengthening Austenite in Reversible Martensite Transformation. V. N. Gridnev, V. T. Cherepin, and N. F. Chernenko. (*Metall. Obrabotka Met.*, 1957, (5), 7–12). Maximum effect of stabilization is observed after the first cycle of treatment. When the number of cycles is increased, there is a further stabilization of austenite but when treated in the range — 75° to + 800° C, even after fivefold cooling and heating, complete stabilization is achieved. The temperature of the reversible martensite transformation during stabilizing treatment remains practically constant. At high rates of heating (1 000° C/sec) the process of strengthening of the austenite is comparatively slow.—R. S.

The Influence of Hot Plastic Treatment on the Isothermal Transformation of Austenite in Cr–Ni–Mo Structural Steel. T. Malkiewicz. (*Hutnik*, 1957, **24**, Nov., 427–436). [In Polish]. Knowledge of the changes in austenite cooled immediately after hot working has a practical value in hardening. The effect of plastic treatment is explained as a result of three factors: (1) coarse grain caused by heating to 1250° C, (2) pressing and (3) recrystallization of austenite which does not take place instantaneously but requires a longer time, the lower the temperature of plastic treatment. T.T.T. graphs for steel containing 0·36%C, 1·43%Cr, 1·46%Ni, and 0·23%Mo for austenitizing temperatures of 850°, 950°, and 1050° C and after heating to 1250° C are shown.

Austenite Homogeneity and Heat Treatment. A. Legat. (*Berg. Hütten. Monatsh.*, 1958, **103**, June, 110–113). The influence of various heat treatments on the homogeneity of austenite is discussed.

The Solubility of Carbon in Austenite from Cast Iron Alloys and its Importance for Heat Treatment. J. Motz. (*Giess. Tech. Wiss.*, 1957, Oct., 943–953). A measuring device for following the absorption of carbon is described, together with the method of making specimens. The measurement of the change in lattice constants of austenite during the absorption of carbon by the specimen is carried out using high temperature X-ray techniques. An interpretation of the results is offered. The influence of the concentration of carbon in the austenite on the T.T.T. diagram of cast iron is described. Micrographs show the texture after different treatments. (28 references).—R. J. W.

Experiments to Clear up the Transformation Behaviour of a Special Carbide Forming Chrome Steel. (*Forsch. Wirts. Nordrhein-Westfalen*, No. 74, 1954, pp. 47). A steel with 0·43%C and 3·52%Cr after a standardized heat treatment was examined and the isolated carbides analysed by micro-methods, X-rays, and the electron microscope. In the pearlite one-fourth of the iron was replaced by chromium in the Fe_3C phase. At 38%Cr the structure went over to Cr_7C_3 the ultimate content being 53%Cr. About 40% of the Cr could be replaced by Fe in this carbide. In the matrix the Fe_3C could contain 6–14%Cr and was of a characteristic form.

On the Characteristics of the Bainite Transformation. K. Tsuya. (*Nippon Kinzoku*, 1956, **20**, Aug., 453–456). A hot-stage microscope is used to study the isothermal formation of bainite, the temperature-dependence of the bainite reaction, surface distortions produced, lowering of M_s temp., and behaviour of bainite during step quenching. Bainite is formed by a shear process governed by diffusion.—K. E. J.

Recent Theories of the Martensitic Transformation in Iron Base Alloys. Transformation Characteristics. M. Doi. (*Bol. A.B.M.*, 1958, **14**, Apr., 215–227). [In Portuguese]. The author endeavours to provide a critical review of the present state of knowledge of this field. (14 references).—P. S.

The Nature of the Martensite Transformation. M. E. Blanter and P. V. Novichkov. (*Metall. Obrabotka Met.*, 1957, (6), 11–14). It is shown experimentally that in the process of martensite transformation there is a continuous variation in the state of the matrix austenite. The phase work-hardening which is produced and the hardening of the retained austenite increases resistance to martensite transformation. The reason for the cessation of growth and nucleation of martensite crystals under isothermal conditions is the increase in the resistance of the matrix in connection with the phenomenon of phase work-hardening and hardening of the retained austenite. To effect further development of the martensite transformation the temperature must be lowered or sufficient deformation stresses must be applied.—R. S.

Crystallography of the Martensite Transformation. J. Karp. (*Hutnik*, 1957, **24**, Nov., 448–452). [In Polish]. Theories of the mechanism of the martensite transformation are described. Mechanisms proposed by Kurdiumow and Sachs and Nishiyama are represented by the translocation of atoms in the plane of the austenite cell.

On the Isothermal Martensitic Transformation in High Speed Steel at Subzero-Temperature. M. Okamoto and R. Tanaka. (*Nippon Kinzoku*, 1956, **20**, May, 285–288). Both isothermal and athermal components of martensite are formed over a range of temperature on cooling. The amount of transformation during isothermal holding on subzero cooling increases with lowering of the holding temp., passes through a max. at a

temp. depending on the prior ageing time, and falls to nearly zero below — 150° C.—K. E. J.

Some Laws of Non-Reversible and Reversible Martensite Transformation. E. L. Vinogradskaya and G. A. Kreslina. (*Metall. Obrabotka Met.*, 1957, (5), 12–15). A complete hysteresis loop of reversible γ–α transformation for an alloy containing 0·06%C, 13·2% Mn, 0·28%Cu, and 2·12%Co showed that hysteresis for the beginning of transition is 240° C. The stabilization of the γ-phase depends mainly on the temperature to which the specimen is heated after primary γ–α transformation. The maximum degree of stabilization during the second γ–α transformation is attained by heating to a temperature corresponding to the end of reversible α–γ transition. Stabilization is apparently caused by stresses in the γ-phase which occur with one-way and with subsequent reversible transformations. The authors point out that the rehardening of hardened parts frequently practised on the shop floor cannot be justified in that heating above the critical points removes the influence of the prehistory of the steel on its subsequent properties.—R. S.

Accommodation Strains in Martensite Formation, and the Use of a Dilatation Parameter. J. W. Christian. (*Acta Met.*, 1958, **6**, May, 377–379). A letter. A mathematical investigation of the dilatation parameter of Bowles and Mackenzie is presented and interpreted in terms of accommodation strains and interface energy.

On the Fine Bands Appearing in the Electron-Micrograph of a Martensite Crystal of Iron–Nickel Alloy. Z. Nishiyama, K. Shimizu, and S. Sato. (*Nippon Kinzoku*, 1956, **20**, June, 325–328). The martensite transformation of a Fe–30%Ni alloy is studied. In the surface relief of the martensite there are fine bands parallel to $(112)_M$ and spaced at a min. of 0·02μ. On the etched surface, however, these hardly occur except near the mid-rib.—K. E. J.

The Habit Planes in Certain Martensitic and Nucleation - and - Growth Transformations. H. M. Otte and T. B. Massalski. (*Acta Met.*, 1958, **6**, July, 494–499). The habit plane of precipitation of Fe_4N and Fe_3P from α-iron is predicted from the phenomenological theory of martensite formation developed by Wechsler *et al.* (*Trans. A.I.M.M.E.*, 1953, **197**, 1503; *J. Met.*, 1953, **5**, 1503). The implications arising from the possibility of extending the martensite theory to diffusion-controlled 'nucleation and growth' transformations are discussed.

On the Mid-Rib of Martensite. Z. Nishiyama, K. Shimizu, and S. Sato. (*Nippon Kinzoku*, 1956, **20**, July, 386–388). Results of electron and optical microscopical examinations are reported. On the surface relief of Fe–30% Ni alloy, most martensite plates have a ridge, on the opposite sides of which the direction of the fine bands differs by up to 7°; this corresponds with the mid-rib. On the etched surface some plates show two parallel mid-ribs or a transient region between two. On the etched surface of Kovar, step structures are found in mid-ribs.—K. E. J.

Certain Regularities in Binary Metal Systems. O. S. Ivanov. (*Doklady A.N.*, 1958, **119**, (6), 1142–1144). Temperature equilibrium diagrams of binary systems of Ti and U, with V, Cr, Mn, Fe, Co, Ni, and Cu, are discussed in the light of the atomic structure.—S. I. T.

An Estimation of the Free Enthalpy Diagram of the Ternary System Fe–Mn–Si at 1600° K. É. Bonnier. (*Compt. Rend.*, 1958, **246**, May 5, 2617–2619). A note. The binary and ternary phase diagrams of the system Fe–Mn–Si are used as the experimental foundation for an estimate of the activity curves of the constituents, based on phase relations, certain characteristics of the solutions, and the Gibbs–Duhem law.—L. D. H.

The Metastable Iron–Chromium Diagram. A. G. Lesnik. (*Doklady A.N.*, 1958, **119**, (5), 978–981). This work presents a quantitative evaluation of the energy of atomic interaction in Fe–Cr alloys, partly on the basis of new experiments on the location of curves of phase equilibria of the α- and γ-phases. Mathematical treatment shows that the formula selected is insufficient to define fully the interatomic interaction.—S. I. T.

Radiographic Investigation of the Austenite-Martensite Transformation in Iron–Nickel Single Crystals under Tensile Stress. A. Kochendorfer and G. Otto. (*Arch. Eisenh.*, 1958, **29**, Dec., 775–784). Radiographic investigation of Fe–Ni single crystals transformed under tensile stresses showed the habit planes to be {531}A rather than {529}A planes as assumed by Nashiyama (*Sci. Rep. Tohoku Univ.*, 1934, 637–664). Both planes have almost the same position, being inclined at only 2°. Of the possible 24 martensite orientations, only 4 actually occur, due to the external stresses.

Studies on the Martensite Transformation in Iron–Nickel Alloys. I. Difference in Microstructure of the "Schiebung" and "Umklapp" Transformations. S. Takeuchi, T. Honma and H. Suzuki. (*Nippon Kinzoku*, 1957, **21**, Jan., 51–55). The "Umklapp" transformation usually occurs in alloys containing over 30%Ni, the "Schiebung" in those below. In alloys of, < 20% Ni areas of the surface have many parallel striations, but each area is homogeneous after etching; in those of 25–30%Ni a Widmanstätten structure appears. Habit planes are described. (14 references).—K. E. J.

Study on the Bainitic Transformation of Cast Iron. M. Hanui. (*Tetsu to Hagane*, 1958, **44**, Mar., 366–368). Magnetic tempering curves are given for a number of austempered specimens which have had various heat-treatments, and relationships are shown between austempering times and hardness, absorbed energy and magnetization.—K. E. J.

A Transitional Hexagonal Closely-Packed Phase in the γ–α Transformation in Certain Fe-Base Alloys. B. Cina. (*Acta Met.*, 1958, **6**, Dec., 748–762). It is known that the h.c.p. ϵ phase, formed martensitically as a transitional phase in some Fe–Mn alloys, also forms in some unstable austenitic Fe–Ni–Cr alloys, and it is shown that the phase occurs in ternary alloys based on Fe–Mn and containing Ni, Cr, Co or C, C having the greatest effect on a weight basis. ϵ was not formed unless the Mn content was sufficient to have caused its formation in binary Fe–Mn alloys, suggesting that Mn was the primary cause of ϵ formation in ternary alloys.

The Present State of Knowledge on the Sigma Phase in Iron–Nickel–Chromium Alloys. R. Ergang, G. Günther and H. Weik. (*Stahl Eisen*, 1959, **79**, Jan. 8, 46–51). A very comprehensive review dealing with: Detection of the σ-phase; Equilibrium diagram Fe–Ni–Cr; Rate of σ-phase formation; Effect of pretreatment on the formation of the σ-phase; Changes in mechanical properties by precipitation of the σ-phase; Mechanism of σ-phase formation; structure of the σ-phase; and effect on corrosion. (60 references).—T. G.

Physical and Metallurgical Properties of Alpha Iron–Silicon Alloys. P. Coulomb. (*Met. Corros. Ind.*, 1958, **33**, Nov., 431–440) The structure, physical properties and techniques of examination of the metallurgical properties of Si–Fe alloys containing + 10%Si are discussed, with reference to the literature. (83 refs.).

The Structure and Magnetic Properties of Some Alloys of the System Fe–C–Al. N. Dzeru, P. Iliyesky, A. Moroyanu and E. Kruchianu. (*Rev. Mét.* (*Bucharest*), 1958, **3**, (2) 5–18). [In Russian]. The microstructure and magnetic properties of 46 Fe alloys with from 1·16 to 2·35%C and from 1·1 to 12·7%Al are examined and tabulated.

The Behaviour of Iron Amalgam on Tempering. G. Jangg, E. Fitzer, O. Adlhart and H. Hohn. (*Z. Metallk.*, 1958, **49**, Nov., 557–562). The chemical behaviour and the effect of heat on electrolytic Fe-amalgam was investigated; special methods of analysis and grain-size measurement used for the purpose are described. The effect of heat treatment on oxidation is discussed.

Studies on Uranium–Iron Alloys. T. Geiger and C. Fizzotti. (*Schweiz. Arch. Wiss. Techn.*, 1958, **24**, Jan., 27–32). Some means of improving the stability of U are described. Experiments with U–Fe alloys were carried out, particularly by means of the "thermal cycling" method. The β-phase is stabilized by small amounts of iron, otherwise isothermal transformation to α-phase occurs by a martensite reaction.—R. P.

Studies on Fe–Al–Ti System Refractory Alloy. On Annealing Hardness and Structure. H. Horiguchi. (*Tetsu to Hagane*, 1958, **44**, Mar., 439–441). The effects of temp. and additional elements (Ni, Co, Mo and Cr) on annealing hardness are described.—K. E. J.

CORROSION

A Critical Analysis of Pitting Corrosion. N. D. Greene and M. G. Fontana. (*Corrosion*, 1959, **15**, Jan., 25t–31t). The literature for the last 35 years is reviewed and theories of the process and methods of investigation are examined. (95 refs.).

On the Colloidal Interpretation of Corrosion and Inhibition Phenomena. J. Frasch. (*Corros. Anticorros.*, 1958, **6**, Jan., 9–14). An attempt is made to correlate the colloidal nature of corrosion products with the electrochemical theory of corrosion and inhibition. Metals with potentials between + 2·8 and + 0·8 volts do not give colloidal solutions and their salts do not form colloids either. If the potentials lie between + 0·8 and — 0·2 volts, the metals form colloidal hydroxides. Between — 0·2 and — 1·2 volt, colloidal metals can form. It is pointed out that the electric charge of the corrosion products is more important than the potential of the metal.—R. P.

Stress Corrosion of Austenitic Stainless Steels. S. Berg. (*Acciaio Inossid.*, 1958, **25**, July-Oct., 115–130). The paper reviews the theories of corrosion under stress and describes researches carried out at the Avesta Laboratories. A description is given of the testing apparatus used and of the preparation of test-pieces. The influence of various corrosive agents and their concentration is examined in detail. The agents studied are the metallic chloride solutions: LiCl, NaCl, KCl, NH_4Cl, $MgCl_2$, $CaCl_2$, $BaCl_2$, $MnCl_2$, $NiCl_2$, $ZnCl_2$, $AlCl_3$, $SbCl_3$, $FeCl_3$, $CuCl_2$ and $HgCl_2$. The effects of the pH, intensity of loading, load cycle and the effects of alloying elements are also studied. (9 References).

The Problem of Corrosion Resistance of Stainless Steel. I. Cornea and S. Zămircă. (*Rev. Mét.* (*Bucarest*), 1958, **3**, July-Aug., 29–39). [In English]. Experiments are described, and illustrated by diagrams and photomicrographs, on the influence of heat-treatment on the resistance to oxidation at elevated temperatures of heat-resistant steel in the form of thin sheet.

The Causes of Susceptibility to Stress Corrosion in Non-Ferrous Alloys and Steels. L. Graf. (*Werks. Korr.*, 1958, **9**, Nov., 696–698). It is shown that tensile stress is not the cause of localized attack; tensile stress produces plastic deformation, thus increasing the activity of the solid solution. Experimental proof of these statements is given.

The Effect of the Wall Temperature of the Rear Surfaces of Boilers on Corrosion by Flue Gases. R. A. Petrosyan. (**Teploenergetika*, 1957, **4**, (12), 16–20). Measurements of corrosion rates in combustion gases from sulphur-containing fuels were made and related to wall temperature. The importance of working above the dew-point is shown.

Corrosion Caused by Flue Gases. O. Farkas. (*Koh. Lapok*, 1958, **13**, Oct.-Nov., 504–508). This corrosion is due to the combustion of sulphur in the fuel to SO_2, and especially to SO_3, and to H_2SO_4 forming at the dew-point. It can be decreased by adding to the flue gas NH_3 or, in oil furnaces, dolomite powder, and by keeping the temperature of the flue gas above dew-point.—P. K.

Boiler Corrosion and its Alleviation by Feed-water Conditioning—(1). A. Laird and N. Reast. (*Corros. Prev.*, 1958, **5**, Feb., 35–38). The authors discuss for the benefit of the non-specialist the aspects of corrosion in low pressure boilers. The problems of boilers at rest and the corrosion in boilers under steaming conditions are dealt with and followed by brief discussions on scab pitting, wasting of boiler

surfaces, high temperature oxidation, necking and grooving, dissimilar metals in contact, stress corrosion, and caustic cracking.—L. E. W.

The Resistance of Ferritic-Pearlitic Steels to Corrosion by Steam and Combustion Products above 530° C. B. Pfenosil. (*Hutn. Listy*, 1958, **13**, (7), 603–611). The corrosion resistance of six Cr–Mo–W–V–Ni steels with various proportions of the alloying elements was studied in the range 530–650° C in steam at 180 atm. and in a corrosive atmosphere obtained by the incomplete combustion of town gas containing also variable amounts of O_2 together with SO_2. The corrosion resistance was similar in steam for all the steels; the upper limit of their usefulness is about 570° C for preheater tubes; small amounts of sulphur have no significant effect on the corrosion rate, but with sulphur contents exceeding 2% there is an increasing tendency for peeling of the protective layer of oxide to take place. This is enhanced in the presence of CO. The steel thus corrodes rapidly even though the rate of growth of the oxide layer is not itself appreciably increased.—P. F.

Internal Corrosion of Tinplate Containers. Y. Kitamura. (*Toyo Kohan*, 1957, **5**, Dec., 43–60). [In Japanese]. Food products, canning and storage conditions, tin coating weight, composition and surface properties of the steel base, all have an effect on rate of corrosion. The electrochemical relationships, effects of dissolved O_2 and of anthocyanins, inhibition by stannous ion and other factors are discussed. Enamelled cans are also considered. (56 refs.).

Corrosion of Steel Pipes in Refinery Installations by Sulphur-Rich Crude Oil. P. Csokán. (*Werkstoffe Korrosion*, 1958, **9**, July, 443–450). It was found that the products of decomposition of the crude oil and superheated steam added to lower the partial pressure of the vapourized oil exerted a strongly corrosive action on the steel structures of the refinery. The nature and structure of the corrosion products are discussed.—L. D. H.

Precipitation Processes and Intercrystalline Corrosion in a Stainless Austenitic Chromium–Nickel Steel Containing Niobium. K. Bungardt and G. Lennartz. (*Arch. Eisenh.*, 1958, **29**, June, 359–364). An austenitic Cr–Ni steel stabilized with 0·5%Nb was examined by analysis of the residue isolated from acid solution and X-ray analysis of precipitation conditions during annealing between 500 and 800° C, after quenching from 900 to 1200° C. The results were related to the resistance to intercrystalline corrosion on testing the specimens in copper sulphate–sulphuric acid solution. Dissolved carbon precipitates on cooling as Nb and Cr carbides, the proportion of the latter increasing at lower annealing temperatures. The effect of varying quenching and annealing temperatures and annealing times is discussed, and reference is made to the effect of the combination of Nb with the nitrogen present in the steel.

Influence of Thermal Treatment on the Resistance to Corrosion of Thin Sheets of 20–9 Stainless Steel Containing Titanium. I.—Atmospheric Corrosion at Elevated Temperatures. I. Cornea and Şt. Zămîreă. (*Studii şi Cercetări de Metalurgie*, 1958, **3**, (1), 19–31). [In Rumanian]. The effect of thermal treatment at high temperatures in the furnace atmosphere on resistance to oxidation of thin sheet (0·96 mm) was examined. The stainless steel examined contained 0·3%Ti. Specimens were heated at various temperatures from 600–900° C for up to 100 h. It was found that a reduction in the amount of ferrite present improved resistance to oxidation; this was attributed to impoverishment of Cr in the austenite grains. Corrosion increased with increased grain size.

A Survey of Corrosion in Packaging—(1). D. V. Weatherley. (*Corros. Prev.*, 1958, **5**, Feb., 47–50, 74). In this first article the author summarizes the causes of corrosion in packaging articles as being due to (1) contamination before protection, (2) inadequate physical barrier, (3) inadequate degree of protection, and (4) corrosion inducing elements in the packaging material. The physical barrier and the choice of the corrosion-prevention method are discussed, as are the problems arising from humidity and the limitations of semi-rigid barriers. Spray packaging is considered and temporary coatings are assessed.—L. E. W.

High-Temperature Corrosion by Hydrogen Sulphide, According to Experiences in Petroleum Refining. P. W. Sherwood. (*Werks. Corr.*, 1958, **9**, May, 273–277). The corrosive action of H_2S at high temperatures in petroleum refining is discussed. The degree of corrosion is largely governed by temperature and concentrations of the H_2S, the lower limit of corrosive attack being 0·006–0·008 mol% H_2S. Choice and treatment of materials to withstand corrosion are discussed.—L. D. H.

Electron Diffraction Examination by Surface Layers of Stainless Steel Attacked by NH_3 Gas at High Temperature. T. Nakayama. (*Nippon Kinzoku*, 1956, **20**, May, 288–291). Surface layers of stainless steels attacked by ammonia containing a little air at 700° C were studied. Iron nitrides (mainly Fe_2N) and spinel-type oxides are formed on 13-Cr and high-Mo steels, and CrN crystals are produced inside these layers. Corrosion surfaces on 18–8 and 25-Cr steels are covered by protective spinel-type oxides, and no nitrides are detected underneath. In 18–8 steel, layers of Ni (or γ-phase containing much Ni) were found inside the oxide layers; these restrict diffusion of metals outwards and of NH_3 inwards.—K. E. J.

The Behaviour of Heat-Conducting Alloys in Nitrogen and in Gases Containing Nitrogen. H. Pfeiffer. (*Arch. Eisenh.*, 1958, **29**, Sept., 575–584). A method is described suitable for determining the behaviour, and in particular the life of heat-resistant alloys at high temperatures in gas mixtures. Annealing Fe–Cr–Al alloys in N_2 showed a reduction in life of about 20% compared with air treatment, whereas an improvement was obtained with Ni–Cr base alloys. The results are discussed.

Influence of Corrosion of Stressed Metals. M. Matejić. (*Zaštita Mat.*, 1957, **5**, (12), 423–427). [In Serbocroat]. The effect of surface treatments on corrosion fatigue, and the use of corrosion inhibitors are discussed in the light of several publications dealing with the subject.—P. F.

The Behaviour of Cast Iron in Acids and Acid Mixtures in the Presence and Absence of Inhibitors. W. Machu and M. G. Fouad. (*Werkstoffe Korrosion*, 1958, **9**, June, 369–379). Loss in weight of cast iron and inhibiting action were examined in various single acids and mixtures with or without organic and inorganic inhibitors. The action of an inhibitor is reduced by surface carbides and silicides.

The Attack of Tin-Bearing Zinc Melts on Iron. D. Horstmann. (*Arch. Eisenh.*, 1958, **29**, June, 397–400). The attack of zinc melts on iron is increased by tin additions. The temperature range of intensified attack proceeding linearly with time, is widened with increasing tin contents and displaced to lower temperatures.

The Attack of Zinc Melts Saturated with Iron on Molybdenum-Bearing Iron. D. Horstmann. (*Arch. Eisenh.*, 1958, **29**, Aug., 463–466). The attack of Zn melts on iron was investigated for Mo contents of up to 5·25%. Additions of Mo at first increased attack; this was however reduced with higher amounts, being less at 5%Mo than with Mo-free iron. The temperature and time dependence of the attack were investigated.

Biological Corrosion and Some of Its Effects. P. Colomb. (*Zaštita Mat.*, 1958, **6**, (2), 61–64). [In Serbocroat]. The origin and mode of operation of corrosion induced by micro-organisms are discussed, and methods of preventing it are considered. A special case of the corrosion due to micro-organisms, which was studied by the author in a hydro-electric power station in the Belgian Congo, is analysed.—P. F.

The Structure of Iron Scale. XI.—Investigation of Scale Produced by the Oxidation of Iron in Carbon Dioxide. V. I. Arkharov, V. P. Mar'evich, M. Reinkhol'b, and M. I. Simonova. (*Fiz. Met.*, 1957, **5**, (2), 251–254). Radiographic examination of specimens heated for various times at 1 000° C in an atmosphere of CO_2 showed that up to times of the order of 7 h only FeO was produced; after 7 to 14 h Fe_3O_4 was formed on the layer of FeO, the time and amount of the deposit depending on the rate of supply of CO_2. The structures of the scales obtained are discussed.—L. D. H.

Accelerated High Temperature Oxidation Due to Vanadium Pentoxide. K. Sachs. (*Metallurgia*, 1958, March, 123–136; April, 167–173). The harmful effect of certain oil ashes on gas turbines is attributed to V_2O_5, alone or with other substances. Investigations are described into the mechanism of attack, secondary effects and the influence of time, temperature etc.—A. G.

Corrosion of Iron and Steel at High Temperature. S. Mrowec, D. Wajszel, and T. Werber. (*Hutnik*, 1958, **25**, Jan.-Feb., 26–34). [In Polish]. Different forms of scale formed on iron and steel are described. Below 560° C the scale is composed of two layers: magnetite and haematite, whilst above this temperature a third layer, 'wustite' (FeO), is formed between the metal and the other two layers. The rate of formation of the scale is determined by the diffusion of iron ions through the scale. In order to obtain heat-resistant steel, it is essential to prevent formation of wustite phase, which can be achieved by adding certain elements or oxides which inhibit ion diffusion.

Grain Boundary Oxidation of Cr–Ni–W Steels. P. Csokán. (*Metalloberfläche*, 1958, **12**, Aug., 230–232). After pointing out the tendency of Cr–Ni–W steels used for structural members to be susceptible to decarburization, with a consequent reduction in fatigue strength, associated with cracking and failure of highly-stressed parts, the author describes experiments on a part made from a steel of this type (1·4%Cr, 4·05%Ni, 1·02%W, 0·22%C). In this case the formation of cracks was attributable to the formation of a heterogeneous intercrystalline phase; decarburization was prevented by giving the steel an electrolytic deposit of copper before heat treatment, subsequently removing the deposit in a pickling bath.—L. D. H.

Oxidation of Fe–Al–C Alloys. M. Vykický, B. Prenosil, and H. Tuma. (*Hutn. Listy*, 1958, **13**, (6), 490–496). The oxidation of Fe–C–Al alloys with C and Al contents ranging from 0·2–3·0 and 9–30% respectively was studied in the range 900–1050° C. With certain alloy combinations blisters formed on the surface of specimens, particularly at higher temperatures. Breaks in the oxidation isotherms accompanied their occurrence. The blister formation was traced to rupture of the protective alumina layer caused by volume changes connected with the transformation of the ε- into the γ-phase.—P. F.

Oxygen Corrosion and the Growth of Cast Iron. Z. Durmala. (*Przeglad Odlewnictwa*, 1958, **8**, June, 164–169). An application of Pilling and Bedworth's theory of corrosion in non-ferrous metals to the corrosion of cast iron, tracing the connection with Wagner's theory of the influence of electrical conductivity on the formation of oxide layers and Krupowski's study of the corrosion protection afforded by oxide layers on the surface of metals. On this basis a study of the influence of various alloying elements on allotropic change temperatures. The author further describes experiments carried out up to 1957 in conjunction with B. Deptuch on the effect of certain alloying elements on the growth of cast iron at elevated temperatures, and the influence of technological factors such as inoculation and vacuum casting.—M. T.

Oxidation of Superheater Materials by High-Temperature Steam. J. Hoke and F. Eberle. (*A.S.M.E.*, 1957, 57–A–175, pp. 10). A transition temperature was found above which oxidation increases rapidly. This is about 1050° F for carbon steel and 1100–1150° F on low-alloy steels. Up to 5%Cr has little effect but 9% markedly increases the transition temperature.

Report of Subcommittee XV on Atmospheric Exposure Tests of Wire and Wire Products. (*Proc. A.S.T.M.*, 1957, **57**, 99–129). The 1955 and 1956 inspection results are tabulated and discussed.

Results of a Weathering Test of Various Steels Protected by Paint Films. G. Becker.

(*Stahl Eisen*, 1958, **78**, Aug. 21, 1 186–1 191). Weathering tests in an industrial atmosphere for up to 22 years on painted steel samples are reported. Composition of the steels, surface pretreatment, type of paint, and mode of paint application were varied. Steels killed by addition of Si and containing small amounts of Cu and Mo show highest corrosion resistance. The critical Cu content is about 0·15%, higher contents do not substantially increase the corrosion resistance. Sandblasting the surface is more effective than descaling by hand. Sprayed paint films show better corrosion resistance than do hand-painted coatings. Iron oxide primers + paints containing metallic zinc were superior to all other coatings.

Comparison between the Result of Exposure to Industrial Air and Short Term Trials in Atmospheres Containing Sulphur Dioxide. A. Kutzelnigg. (*Werkstoffe Korrosion*, 1958, **9**, July, 429–434). Industrial air is defined, and the results of exposure tests in industrial air are compared with those of accelerated laboratory corrosion tests in the Kesternich Tester apparatus, with particular reference to the effect of atmospheres containing SO_2. Good agreement was obtained for nickel deposits and for zinc and other paint systems. (20 refs.).—L. D. B.

Comparative Field Tests for Determining the Resistance to Corrosion of Electrolytic Zinc Deposits Passivated by Various Chemical Methods. T. Biestek. (*Werkstoffe Korrosion*, 1958, **9**, July, 434–440). Field tests were carried out to determine the resistance to corrosion of steel specimens with electrolytically deposited zinc coatings, untreated, passivated or treated in a variety of chemical baths, and exposed to different atmospheric conditions. Passivation increased the resistance to corrosion as much as 15 times, and variation of the chemical treatment had an important influence. The results are classified.

Programme of New Field Trails to Study the Influence of the Quality of Pre-treatment, Amount of Surface Corrosion and Other Factors on the Durability of Paint on Steel Sheet. Standards for Determining Quality of Treatment. K. F. Trägårdh. (*Werkstoffe Korrosion*, 1958, **9**, July, 424–429). As field trials have already shown that the life of paint coatings on steel is affected by the preliminary derusting of the metal, a series of exposure tests has been arranged to investigate more fully the effects of preliminary treatment on the durability of the coatings. The programme is described in detail.—L. D. B.

Field Tests of Atmospheric Corrosion of Hardware. (*Proc. A.S.T.M.*, 1957, **57**, 130–133). Inspection tests on structural shapes and tubes in various steels with galvanized, aluminized, sherardized, lead-plated, and similar finishes are tabulated.

Steady Potential and Cathodic Polarisation of Active Chromium. T. Heumann and B. Roschenbleck. (*Werkstoffe Korrosion*, 1958, **9**, June, 383–390). Cathodic polarization curves and steady potentials as a function of pH value were measured on active Cr and an Fe–Cr alloy containing 25–6%Cr. The steady potential was found to deviate from that of the reversible H_2 electrode, and this result is discussed. In the range of pH values investigated, the cathodic polarization curves of H_2 evolution are parallel.

Electrochemical Methods for Studying Corrosion. M. Pourbaix. (*Schweisstechnik*, 1958, **12**, June, 71–83). A general survey of electrochemical techniques for studying corrosion, illustrative examples including the cathodic protection of iron, polarization of iron in solution, and corrosion of iron in contact with concrete.

Corrosion Resistance of Metals in a Petroleum Gas Medium Containing Hydrogen Sulphide. V. M. Nikiforova and N. A. Reshetkina. (*Metall, Obrabotka Met.*, 1957, (5), 55–62). The corrosion behaviour of materials in petroleum gas depends largely on the hydrogen sulphide and moisture contents. Special heat-resisting cast irons containing Al were tested under laboratory conditions where the humidity and H_2S contents were higher than those under service conditions. Silicon iron exhibited the maximum corrosion resistance. Chromium iron and heat resisting aluminium cast iron (9%Al) manifested higher corrosion resistance than grey iron. Although Cr additions improved corrosion resistance, galvanizing and calorizing grey cast iron did not produce results.—R. S.

Equipment for the Investigation of Corrosion in Flowing Liquids and Strongly Aggressive Media. V. Seifert, J. Vorlíček, K. Smrček, and I. Sekerka. (*Coll. Czechoslovak Chem. Comm.*, 1958, **23**, Mar., 557–559). A description is given of the construction and mode of operation of an all-glass apparatus for the investigation of metallic corrosion in flowing corrosive liquids. It is considered that the equipment can be enlarged to incorporate other types of corrosion tests.—L. D. B.

Survey of Polish Work in the Field of Short-Term Testing of the Resistance to Corrosion of Electrolytic Coatings. T. Biestek. (*Werks. Corr.*, 1958, **9**, May, 271–273). A short description of work carried out recently in Poland on rapid methods for testing the resistance to corrosion of zinc and other coatings.—L. D. B.

The Corrosivity of Waters. Behaviour of the Galvanic Couple Steel–Copper in Saline Solutions. G. Bombara. (*Met. Ital.*, 1958, **50**, July, 263–272). [In Italian]. Results of tests are given showing the galvanic corrosion of steel coupled with copper in salt solutions of different concentrations. The most significant factors are the values of the corrosion current and of the protective cathodic current. The potential values, however, whether of the corrosion or of the protective currents, are shown to be of little significance. Galvanic methods of investigation are suitable for evaluating the merits of inhibitors. Tables of statistical data are given. (7 references).

Examination of Electrodeposited Protective Coatings for Corrosion-Resistance by Short-Time Tests. D. Horstmann. (*Stahl Eisen*, 1958, **78**, Aug. 21, 1 207–1 209). A review of concepts and methods published in the literature on the value of short-time corrosion tests. A number of corrosion-testing devices including the BISRA apparatus are briefly described and discussed. (34 references).—T. G.

Standard Trials for the Study of Corrosion of Iron and of Cathodic Protection Against Corrosion in the Ground. (*Corros. Anticorros.*, 1958, **6**, May, 171–176). The conditions which determine the aggressive character of a soil are examined, i.e. structure, and chemical and physical properties. The relation between intensity of corrosion and the rates of soil moisture to the air content of the soils was established by burying iron plates in different types of soil, and the effect of the factors examined on the efficiency of cathodic protection are considered.

Method of Measuring the Rate of Dissolution of Corroding Metals in Solutions Containing Air. H.-J. Engell. (*Arch. Eisenh.*, 1958, **29**, Sept., 553–558). The method described depends on small changes in the electrode potential of the metal. The method can be used to determine rate of corrosion almost without retardation, and was tested on a mild steel in artificial sea water.

Electrochemistry and Corrosion—Recent Work in Russia. (*Corros. Prev.*, 1958, **5**, Feb., 42–43). This article is a summary of a study of the limiting cathodic current and its relation to rate of corrosion of copper in dilute nitric acid. The temperatures investigated were 25°, 60°, and 90° C and the experimental results, as graphed, show that, apart from HNO_3 concentrations of 10·2 and 12·5 mol./l., the rates of corrosion at these temperatures were close to the limiting cathodic current densities. The author's discussion of his results is condensed and critically assessed.

Study of the Corrosion Properties of Non-Drying Oils and Greases, with Particular Reference to Modern Lubricants and Metal Preservatives. A. Bukowiecki. (*Schweiss. Arch. Wiss. Tech.*, 1958, **24**, July, 201–217). A general review of the subjects indicated in the title, with reference to the literature, and to experiments carried out by the author. The first part consists of a general description of the non-drying oils and greases of practical importance and a statement of the corrosion problems encountered.

Thermogalvanic Corrosion. V. V. Gerasimov and I. L. Rosenfel'd. (*Izvest. Akad. Nauk, Otdel. Khimi.*, 1956, (1), 29–31). Investigations are described involving the measurement of thermogalvanic current in cells of various metals, including iron, with acid, neutral, and alkaline solutions, and with different anode and cathode surfaces.

Nitric–Hydrofluoric Acid Evaluation Test for Type 316L Stainless Steel. D. Warren. (*A.S.T.M. Bull.*, 1958, May, 45–56). Testing with 10%HNO_3–3%HF can be used to evaluate intergranular corrosion resistance, being sensitive to precipitated carbide and insensitive to sigma-phase. Optimum conditions are two 2-h periods at 70° C. Large numbers of heats of steel were tested and the findings are tabulated.

Electrochemical Behaviour of Bimetallic Electrodes and the Application of the Over-potential Curves of These Electrodes to Corrosion Research. G. Bianchi and G. Caprioglio. (*Werkstoffe Korrosion*, 1958, **9**, July, 440–443). If a 2-phase electrode with the local cells formed on its anode and cathode surfaces is connected to an external circuit, the polarization voltage is a function of the position and size of the local cell areas, anodic and cathodic reactions, direction and strength of the applied current and the position of the end of the reference electrode in the solution. These facts are made the basis for an investigation of current-potential curves of electrodes which are corroded by local currents.—L. D. B.

Resistance to Intercrystalline Corrosion of Welded Joints Made of 18–8 Steel. J. Nemec. (*Hutnik*, 1957, **24**, Sept., 356–363). [In Polish]. The effect of additional cooling with water in the welding of 18–8 steel was investigated. In the case of steel containing 0·08–0·10%C and no Mo a considerable reduction of intercrystalline corrosion was achieved. No reduction of corrosion was obtained for steel containing 0·11%C. Practical use of the water cooling method is limited and it is applicable only in special cases.

The Elements in a Decision-Statistical Study of a Case of Corrosion. C. Meyer. (*Corros. et Anticorros.*, 1958, **6**, Sept., 298–317). When replacing an oil tank it was desired to assess the corrosion as an aid to designing the new tank. The problem has been treated as one of sampling and statistical analysis.

Vapour Phase Inhibitors. G. Mantovani. (*Corros. Anticorros.*, 1958, **6**, July-Aug., 258–264). The results of a series of trials by the author on the characteristics of several vapour-phase inhibitors are discussed; conclusions are drawn respecting the mechanism of their action. (34 ref.).

The Electrolytic Corrosion of Cast Iron and Ms60 Brass in Acids in the Absence and Presence of Inhibitors. II. W. Machu and M. G. Fouad. (*Werks. Korr.*, 1958, **9**, Nov., 699–715). The loss in weight of the combination cast iron–brass Ms60 was investigated in various acids and acid mixtures, with and without inorganic and organic inhibitors. It was found that the inhibitors mainly restrained corrosion due to local cells, and had only a slight influence in electrolytic corrosion. The results are discussed.

Weather Versus Cathodic Protection of Underground Pipe Lines. F. E. Costanzo. (*Corrosion*, 1958, **14**, Aug., 363t–368t). A 4 mile section of 20-in. bare pipe line in Pennsylvania protected cathodically was examined in relation to rainfall, soil temperature and mean daily temperature and compared with rectifier current output. Temperature had little or no effect, rain of over ½ in. changes current requirement, but this falls to normal when the rain stops. Snow has much less effect.

Zinc as a Cathodic Inhibitor. H. B. Jonassen. (*Corrosion*, 1958, **14**, Aug., 375t–376t). The form of complex salt produced in solution from Zn in contact with Ag is elucidated.

Surface Tension Phenomena and the Chemical Treatment of Materials for Corrosion Protection. R. Toitel. (*Corros. Anticorros.*, 1958, **6**, Feb., 66–68). Surface tension plays

an importan part in obtaining good contact between the metallic surface and the solution employed. The author shows the technical and economic advantages in using surface-active agents in corrosion prevention.—R. P.

Some Interesting Properties of the General Electric Field. D. Petrocokino. (*Corros Anticorros.*, 1958, **6**, July-Aug., 241–251). The author, after outlining the physical properties of protective films of paint or varnish in metals, discusses modern theories of adsorption and the influence of a static electric field on corrosion.

Methods for Preventing Corrosion in Iron and Steel. II. D. Iturrioz. (*Met. Elect.*, 1958, **22**, Sept., 99–105). The use of phosphating and various metal coatings for corrosion protection is discussed.

Protection of Steel Against Underground Corrosion. K. F. Trägårdh. (*Corros. Anticorros*, 1958, **6**, Sept., 292–297). Possible methods of protection are reviewed. On the basis of long-term field trials, recommendations are made on the protection appropriate to weakly and strongly corrosive soils.—A. G.

ANALYSIS

Simple Analytical Control for Small Foundries. W. A. Burford. (*Eng. Foundryman*, 1958, **24**, Aug., 44–47). A centrifugal method is described for the estimation of several elements in copper and copper alloys. The idea is to obtain with the aid of the centrifuge the volumes of various precipitates formed, these being converted into percentages by multiplying with appropriate factors. In the discussion, the author said that the method could be adapted to the analysis of iron and steel.—T. G.

Pneumatic Transport of Samples in a Steelworks. J. Beauchamps. (*Techn. Mod.*, 1958, **50**, Dec., 535–537). An account of a tube 250 m long for carrying steel samples to the laboratory by compressed air. The analysis is sent back by teleprinter.

Photometric Determination of Manganese in Steel and Cast Iron. J. E. Bolzan. (*Chem.-Analyst*, 1958, **47**, Dec., 95–96). A persulphate–silver method is used.

The Determination of Manganese in Iron and Steel with the Minimum Amount of Silver Nitrate. H. J. Thomann. (*Geissereitechn.*, 1958, **4**, Nov., 292–294). Conditions are standardized for the determination of Mn in cast iron or steel by the persulphate method, using the minimum amount of $AgNO_3$ and a sample weight of 0·1 g for cast iron and 0·29 for steel.

The Electrolytic Separation of Manganese At the Mercury Cathode. G. Jangg, G. Zwerenz. (*Metall.*, 1959, **13**, Jan., 31–36).

The Use of the Tungsten Electrode in the Potentiometric Determination of Manganese in Steels. R. Suarez Acosta. (*Inst. Hierro Acero*, 1958, **11**, 177–179). [In Spanish]. A comparative study has been made between the results obtained using a W electrode and those using a calomel electrode; the results are equally accurate, but the technique with the former electrode is simpler. Details of the tests are given.—P. S.

Separate Determination of Niobium and Tantalum in Special Steels Using Photometric Methods. E. Grossfuss. (*Neue Hütte*, 1958, **3**, Dec., 753–757). The separation and photometric determination of Nb and Ti in W-bearing Cr–Ni steels is described.

Determination of Titanium with Cupferron: (Ethylenedinitrilo) tetra-acetic Acid as Masking Agent. K. L. Cheng. (*Anal. Chem.*, 1958, **30**, Dec., 1941–1945). Absorption is in the ultra-violet.

Determination of Cerium in Steels. I. Application of Knorre's Method. II. Separation of Hydroxide, Extraction of Aluminium Acetate and Colorimetry by Use of Oxine. W. Sekimoto. (*Tetsu to Hagane*, 1958, **44**, Mar., 255–257; 257–260).—K. E. J.

Spectrographic Control of the Zinc Bath in the Sendzimir Continuous Cooling Process. A. Porta. (*Met. Ital.*, 1958, **8**, Aug., 325–328). The paper describes tests carried out at Cornigliano on a continuous galvanizing plant recently installed. The process uses an A.R.L. "multisource" arc-like discharge between a flat cast zinc plate and a graphite counter electrode. The elements determined are Al in concentrations between 0·01 and 0·30% and Pb between 0·05 and 0·60%. A method of preparing standard samples is described and data are given on the reproducibility and accuracy of the process.—M. D. J. B.

Recent Applications of the Electronic Sounding Microanalyser. T. Philibert. (*Met. Ital.*, 1958, **50**, Sept., 402–406). The paper describes a new type of X-ray spectrometer, the electronic sounding microanalyser, for elementary analysis of metallic or insulating materials. Examples of practical application are given. (12 References).—M. D. J. B.

Analytical Chemistry of Fused Media. (*Anal. Chem.*, 1958, **30**, Dec., 1892–1894). A brief report of a symposium. Nothing of direct interest for ferrous metals is included.

Rapid Analytical Techniques at Canadian Exploration Limited. B. Wilson. (*Trans. Canad. I.M.M.*, 1957, **60**, 85–88). The analysis of W, Pb, Zn ores is indicated.

Determination of Small Amounts of Copper in Iron Ores. B. Simó. (*Koh. Lapok*, 1958, **13**, July, 341–343). A rapid and exact analytical method is described for determining small amounts of Cu in iron ores as a copper–pyridine–thiocyanate complex.—P. K.

Study on the Chemical Analysis of "Sand Iron" and Ilmenite. II. Determination of Phosphorus, Manganese, Lime and Magnesia. S. Wakamatsu. (*Tetsu to Hagane*, 1958, **44**, Mar., 306–308).—K. E. J.

Polarographic Determination of Iron and Manganese in Ores and Metallurgical Products. I. M. Issa, R. M. Issa and I. F. Hewaidy. (*Chem.-Analyst*, 1958, **47**, Dec., 88–90). Methods for Mn in steel or cast iron and Mn and Fe in ores are given, using triethanolamine.

Developments in Silicate Analysis. (*B.I.S.R.A. Summary* 128, pp. 2. A brief review referring to the British Ceramic Research Association and U.S. Geological Survey methods.

The Rapid Analysis of Silicate Rocks and Minerals. J. P. Riley. (*Anal. Chim. Acta.*, 1958, **19**, Nov., 413–428). Methods are described for the rapid and accurate analysis of silicate rocks, including alkali metals determination.

Methods of Gas Analysis. (*B.I.S.R.A. Summary* 129, pp. 2). A general review of sampling methods, reagents and methods of analysis.

The Determination of Microgram Quantities of Sulphur in Industrial Gases. E. Abel and H. Barth. (*Arch. Eisenhütt.*, 1958, **29**, Nov., 683–684). The method developed by H. Stratmann for the determination of SO_2 in the atmosphere has been applied satisfactorily to the determination of the total sulphur content of industrial gases. Its application to solid and liquid substances is advocated.

INDUSTRIAL USES AND APPLICATIONS

The Characteristics of Steels for Metal Structures. Herbiet. (*Prat. Soud.*, 1958, **12**, Jan., 1–5). An outline of the characteristics of structural steels of various compositions, with reference to their welding properties.

Progress in the Development and Application of Steel Plates. W. Barr. (*JISI*, 1959, **192**, June, 109–117). [This issue].

Steel for Prestressed Concrete. L. Thomas. (*Tekn. Ukeblad*, 1958, **105**, Nov. 20, 1011–1018). Problems connected with the quality of steel used in reinforcing concrete are discussed from the metallurgical and mechanical standpoints. The first part deals with the structures of various types of steel, and outlines the properties of steel intended for reinforced concrete.

High-Tensile Bolts for Steel Construction. O. Steinhardt and K. Möhler. (**Berichte des Deutschen Ausschusses für Stahlbau*, 1954, (18)). Tests are described on the strength, composition and shaping of bolts for steel constructions. Behaviour and load-bearing capacity are assessed.

Steel as a Basis for Hard-Metal Tipped Mining Tools. F. Fechter and E. Oberdorfer. (*Berg-Hütten. Monatsh.*, 1958, Feb., 26–28). The authors review the history of mining tools briefly and go on to discuss the requirements to be fulfilled by modern tools, particularly drills. The influence of chemical composition and of heat treatment on the application and life of drills is discussed.—R. P.

Operational Experiments on New Types of Steels at the Mosenergo Thermal Generating Station No. 9. V. V. Polyakov and V. A. Larichev. (*Teploenergetika*, 1958, (12), 44–48). The results are given of experiments carried out over a period of 4 years on the corrosion and erosion of medium and high-alloy heat-resisting austenitic steel tube clusters under operational conditions (temperatures from 550–700° C and pressures < 140 atm.). Changes in mechanical properties and creep were also investigated. The experiments are still in hand, and the range of alloys under investigation is being extended. Metallographic analyses confirm the other results obtained.—M. T.

Heat-Resistant Stainless Steel for Power Generating Equipment with Steam Temperatures up to 600° C. E. S. Ginzburg. (*Metall. Obra. Met.*, 1958, (6), 47–52). The 12%Cr stainless steels are limited to use at 420–480° C by their heat-resistance. Additions of Mo, W, V and other elements were made to improve this using a composition 0·16–0·21%C, 11·5–12·5%Cr and 0·6–0·8%Ni. Various recommendations are made.

Steels for Use in Steam Power Plant Operating above 950° F: Creep, Stress-Relaxation and Metallurgical Properties. R. W. Ridley, A. I. Smith, D. J. Armstrong and M. A. Cook. (*Electrical Research Association Tech. Rep. J/T* 170, 1957, pp. 59). Stress relaxation tests at a constant total strain of 0·15% for times exceeding 20 000 h on three low-alloy steels constitute the main part of the report. Changes of impact values after stress relaxation testing are also measured.

Increasing to 640° C the Working Temperature of Flat Sealing Springs of Steam Turbines. T. I. Volkova. (*Metall. Obra. Met.*, 1958, (6), 21–25). Relaxation tests on U.S.S.R. and imported steels and Ni alloys were carried out to find a material with residual stresses not below 12 kg/mm² after 10 000 h at 585–640°. Tests were carried out for 2 100–4 300 h and materials stable at 585° were tested again at 640° and with initial stresses of 40–60 kg/mm². All but one of the steels tested were satisfactory at 585°, steels EI612, EI673 and alloy EI765 serving also at 640°.

Calculation of the Most Suitable Dimensions for Superheater Tubes on an Economic Basis. R. Pich and H. Haupt. (**Energie*, 1957, Aug., 287–293). With special reference to austenitic steels, the material, diameter and wall-thickness of tubes are examined and tables and diagrams for making comparisons of costs are presented. (35 refs.).

Steels and Alloys for Electrical Resistances. J. V. Lopez. (*Anal. Mec. Elect.*, 1958, **35**, Sept.-Oct., 231–245). The characteristics of steels and alloys for electrical resistances are discussed, and their manufacture and testing are described.

Research on the Life of Steel Cables. S. Bellone. (*Acciaio Costr. Met.*, 1958, **10**, Sept.-Oct., 241–245). The difficulty of forecasting the life of steel cables, even when operating conditions are known, is stressed. The merits of Klein's, Zignoli's and Miemann's formulæ are discussed. Researches carried out over a number of years on the behaviour of colliery winding cables, rope railway cables, crane cables and arc furnace electrode cables, are described. The author concludes that cable life can be increased by the careful choice of cable and insisting on a makers' guarantee. Cable construction has an important effect on life.—M. D. J. B.

HISTORICAL

Results of Recent Excavations of Prehistoric and Early Iron Smelters in Bohemia and Moravia. R. Pleiner. (*Stahl Eisen*, 1958, **78**, Nov. 27, 1748–1754). The author reports the results of excavations carried out in Czechoslovakia, particularly Bohemia and

Moravia after the Second World War. The development of iron smelting from the sixth century B.C. to the eleventh and twelfth centuries A.D. is described.—T. G.

Trial Runs with a Prehistoric Bloomery Furnace. J. W. Gilles. (*Stahl Eisen*, 1958, **78,** Nov. 13, 1690–1695). A bloomery furnace of the La-Tène period was built at a place in the Siegerland where previously the remains of such furnaces have been found. The present furnace was charged with charcoal, it had natural draught only. The highest temperature measured was 1420° C. The yield was 11%, the iron produced was spongy and embedded in the slag, its carbon content was 0·09%. The furnace and its operation—lasting about 30 h—is described in detail. With the experience gained in this trial, further runs will be carried out.—T. G.

Anniversaries of Interest to the Iron and Steel Industry Occurring During 1959. H. Dickmann and G. Bauhoff. (*Stahl Eisen*, 1959, **79,** Jan. 8, 41–44). Historical, of interest mainly in Germany.—T. G.

The Metallurgical Work of Réaumur. V. Zsák. (*Koh. Lapok*, 1958, **13,** August, 380–387). The article contains a description of Réaumur's life, and metallurgical work, especially in iron casting and steel carburizing.

Nasmyth and His Steam Hammer. M. Schofield. (*Iron Steel*, 1958, **31,** Sept., 452). A brief outline is given of the career of James Nasmyth, inventor of the steam hammer, which was first used at Le Creusot in 1840.

A Great French Metallurgist: Abraham Fabert. (*Aciers Fins Spéc.*, 1958, Dec., 117–120). A brief biography. 1599–1661. He ran a forge and arms factory at Sedan, was the forerunner of Vauban and became Marshal of France.

ECONOMICS AND STATISTICS

Initiatives, Expectations and Ideas for the Extension of the Iron and Steel Industry. H. Schenck. (*Stahl Eisen*, 1959, **79,** Jan. 8, 1–8). Statistical. A lecture concluding that the present generation should work harder and should provide better education for the coming generation.—T. G.

The Change in Steel Mill Products. (*Steel*, 1958, **143,** Sept. 15, 172–177). Largest growth is forecast for stainless steel, light shapes, plates, piling and rebars. Demand for other steel products is reviewed, considering alternative materials.—A. G.

MISCELLANEOUS

Accidents in the German Iron and Steel Industry During 1957. (Works Statistics). H. Antoni. (**Stahl Eisen*, 1958, **78,** Dec. 25., 1891–1898). Statistical. The figures for Germany are compared with those of other countries. The percentage of fatal accidents decreased considerably in Germany during 1957 as compared with 1956.—T. G.

The Use of Reflecting Substances is Heat Protection. E. A. Müller. (**Verhandlungen der Deutschen Gesellschaft fur Arbeitsschutz*, 1958, **5,** 158). A discussion of the physical processes of reflection and absorption of heat and of the physiological effects of radiation. Textiles combined with Al foil are tested for heat-protective properties and the development of a linked disc product is described.

Fighting Noise in Workshops Taking into Account the Noise Spectrum. R. Köhler. (*Stahl Eisen*, 1959, **79,** Jan. 8, 37–41). The noise in machine shops should not only be judged by its level, but also by its frequency distribution. Examples show that if the noise spectrum is taken into account it is much easier to reduce the absolute level. Some case histories are included.—T. G.

The Noise Environment and its Evaluation in Iron and Steel Works. S. Ogawa, E. Hayashi and T. Takuma. (*J. Hygiene Iron Steel Ind.*, 1957, **6,** Nov., 4–11). **Research on Surroundings and Conditions in an AT-2 Type Audiometry Box.** M. Hisanari, T. Miura and S. Inui. (12–16). **Prevention of Noise in an AT-2 Type Audiometry Box and the Influence of Noise on the Results of Measurements.** M. Hisanari, T. Tokunaga and S. Inui. (17–21). **Heat Injuries Occurring in Steelworks.** M. Kawai and A. Takenouchi. (22–29). **A Study of Labour Hygienic Conditions on the Open-Hearth Furnace.** S. Shinjo and H. Muramoto. (1958, **7,** Feb., 10–18). A comparison of plants at which heat stroke has and has not been observed. **On the Vitamin Excretion of the Iron and Steel Worker.** S. Shinjo, Y. Nanbu, H. Muramoto, M. Suzuki, A. Arino and K. Yuhi. (19–23). Observations after administration of B_1 and C tablets are reported. **Skin Examination of Employees of a Certain Blast Furnace Cement Manufacturing Plant.** M. Nakamura. (24–27). **Recent Advances in Iron and Steel Industry Observed from the Standpoint of Industrial Health.** S. Ogawa. (May, 1–18). Technical improvements at the Hirohata works in the second rationalization of the industry are outlined and the improvement of labour conditions effected, studies on workers in hot environments, a survey of causes of sickness in the various departments and of accidents in handling and transport are reported. **Life Tables for the Workers and Their Families at the Yawata Iron and Steel Works for 1954 and 1955, and a Life Table for Each Department for 1953–55.** H. Mizushima, N. Hata, N. Motoda, M. Kawai, S. Shinjo, K. Matsuura and T. Shigematsu. (19–31). **Studies on Labour Age in an Iron and Steel Co. 10. Labour Age and Service Year Distribution of the Female Workers and the Classification by the Rules for Allotting Duties.** N. Motoda and K. Harada. (32–38). **11. Labour Age and Service Year Distribution of the Female Workers Classified by Body Load of the Work.** (Aug. 6–13). **12. Labour Age and Service Year Distribution of Female Workers Classified by the Nature of the Work.** (13–17). **13. Correlation of the Age and Service Year of Female Workers.** (17–22). **Application of the Donaggio Urine Test for Industrial Fatigue.** K. Harada. (32–39).

Meteorites, Satellites and Ceramics. J. S. Rinehart. (*Amer. Ceram. Soc. Bull.*, 1958, **37,** Nov., 461–467). The surface condition of meteorites is discussed in relation to the problem of satellite construction and the role of ceramics in this application.—A. G.

BOOK NOTICES

EXTERMANN, R. C. (Editor). "*Radioisotopes in Scientific Research.*" (Proceedings of the UNESCO International Conference, Paris, Sept., 1957). 2 Vols. (4 in all). I. Research with Radioisotopes in Physics and Industry. II. Research with Radioisotopes in Chemistry and Geology. $10\frac{1}{4} \times 6\frac{3}{4}$ in., pp. xxi + 761 and xxi + 741. (Indexed separately). Illustrated. 1958, London, New York, Paris, Los Angeles: Pergamon Press. (Price £7 each volume).

This is another of the very large symposium reports, cutting across all the sciences, to which we are becoming more and more accustomed. Lack of contact between the sciences has become a very real phenomenon, not perhaps a problem, as yet, and a very valuable bridge between them must be the workers with specialized techniques who, approaching through very diverse courses of basic training, find themselves with so much in common and so much to contribute, not, perhaps, in their speciality alone. It might well be that much would be lost if there were specific radioisotope scientists, or electron microscopists to name the most obvious parallel. It may be that the advance of science depends much more on the worker with the ability and training to formulate problems than on the worker with merely the technique to solve them. The immediate criticism of this immense work, not one to which there is any remedy, is that it is so large and sectionalized that it may fail to attract its readers outside their own fields—a much greater danger than that this should happen at the Conference itself. One very satisfactory feature, again not connected with subject matter, is the comparatively short time it has taken to issue the volumes. Other "Proceedings" could be mentioned which drag on interminably and somehow are not worth consultation by the time they eventually appear. It would not be possible here even to give the titles of the 200 papers read, and those of interest to the Iron and Steel Industry are abstracted in this issue of the Journal. However, the abstracts alone would not be sufficient to indicate the amount of valuable information contained in the two volumes here reviewed, as the solution to any specific problem may well be found in a quite unexpected setting and it must be made clear that the purely metallurgical topics are very far from exhausting the interest and value of this report.

There are a few minor points. The Russian names are transliterated in an unfamiliar fashion. Each paper has a summary in English, French, Spanish and Russian and the authors' names are not always given in the last-named. On p. 409 of Vol. I, in the Russian summary the author's name is given as "Malkevich", but should apparently be "Bojarski." In the Russian summary on p. 386 of the same volume "Palatnik" is misspelt "Palatkin," reference to the papers quoted shows the former to be correct. These are very minor errors, which would hardly be noticed in ordinary reading, except, perhaps, by a Russian!

In Volume II the pagination of the text and table of contents are out of step owing to the omission of a paper by Coekelbergs *et al.* which should have started on p. 401; this is corrected near the end by omission of the page no. in the table of contents for the paper by T. P. Kohman *et al.* which actually begins on p. 661.—J. G. COCKBURN.

NEW PUBLICATIONS

AMERICAN SOCIETY FOR METALS, "*Powder Metallurgy in Nuclear Engineering.*" Proceedings of the Conference on Powder Metallurgy in Atomic Energy, October 20, 1955. Philadelphia. 9 × 6 in., pp. ix + 275. Illustrated. Cleveland, 1958: The Society. (Price $8.50).

AMERICAN SOCIETY FOR TESTING MATERIALS. "1958 *Book of ASTM Standards Including Tentatives.*" 9 × 6 in. Illustrated. Part 2: Non-Ferrous Metals (Specifications), Electronic Materials, pp. xxvii + 1358. Part 4: Cement, Concrete, Mortars, Road Materials, Waterproofing, Soils, pp. xxx + 1426. Part 9: Plastic, Electrical Insulation, Rubber, Carbon Black, pp. xxxiv + 2202. Philadelphia, 1958: The Society.

AMERICAN SOCIETY FOR TESTING MATERIALS. "*Symposium on Non-Destructive Tests in the Field of Nuclear Energy.*" S.T.P. No. 223. 9 × 6 in., pp. viii + 395. Illustrated. Philadelphia, 1958: The Society. (Price, Non-members $10.00; Members $7.50).

AMERICAN WELDING SOCIETY. "*Welding Handbook,*" Part II. Welding Processes: Gas, Arc and Resistance. 4th edition. 9 × 6 in., pp. vi + 13 chapters [not continuously paginated] + Index. Illustrated. London, 1959: Cleaver-Hume Press Ltd. (Price £3 12*s*).

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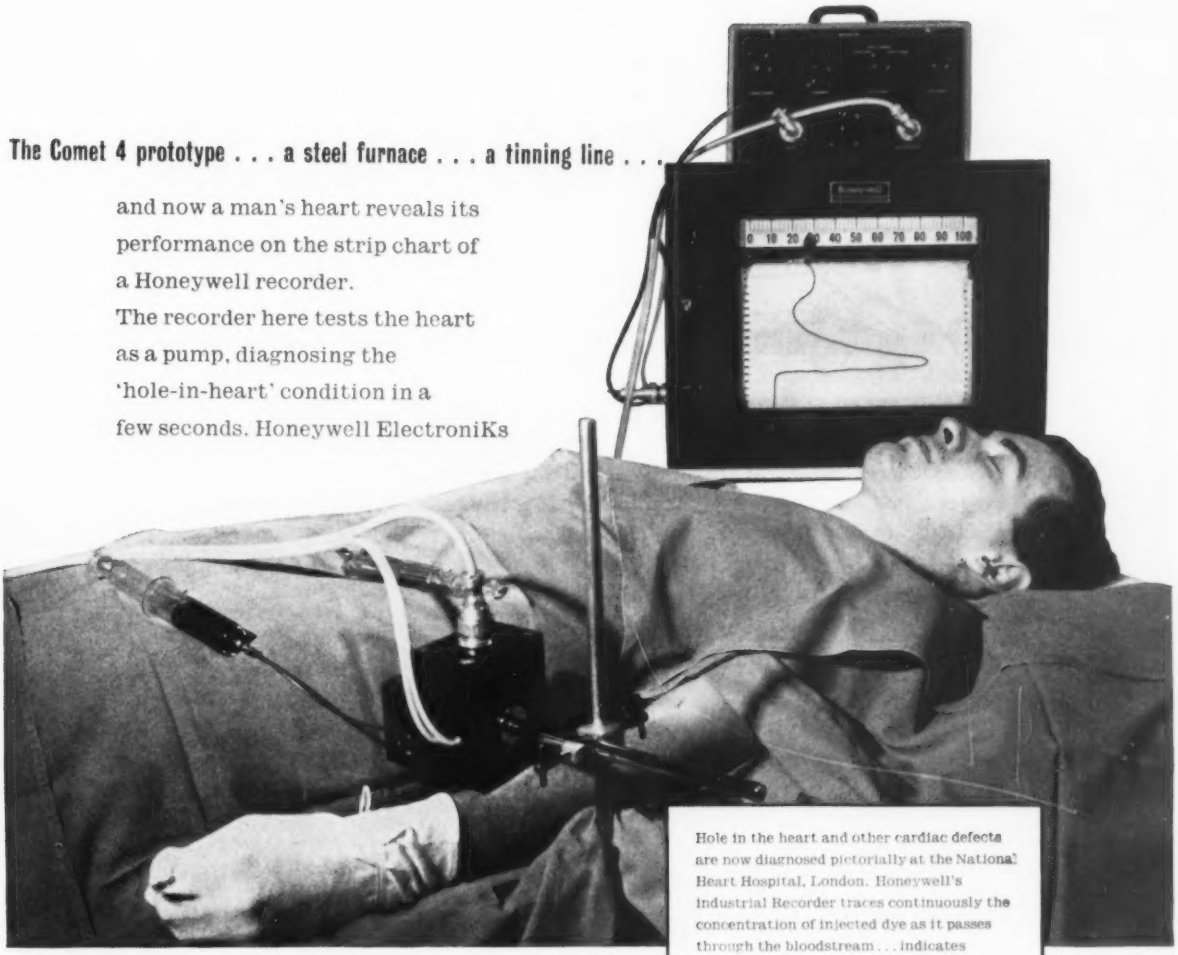

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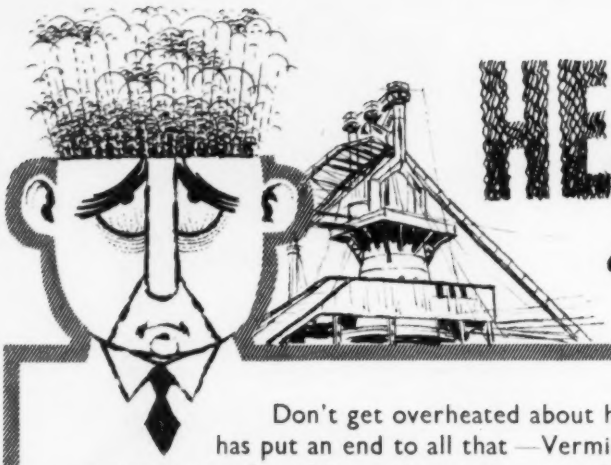

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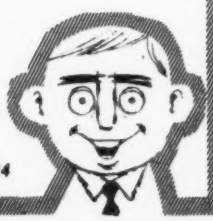

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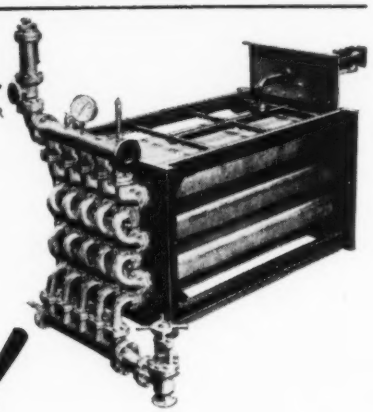

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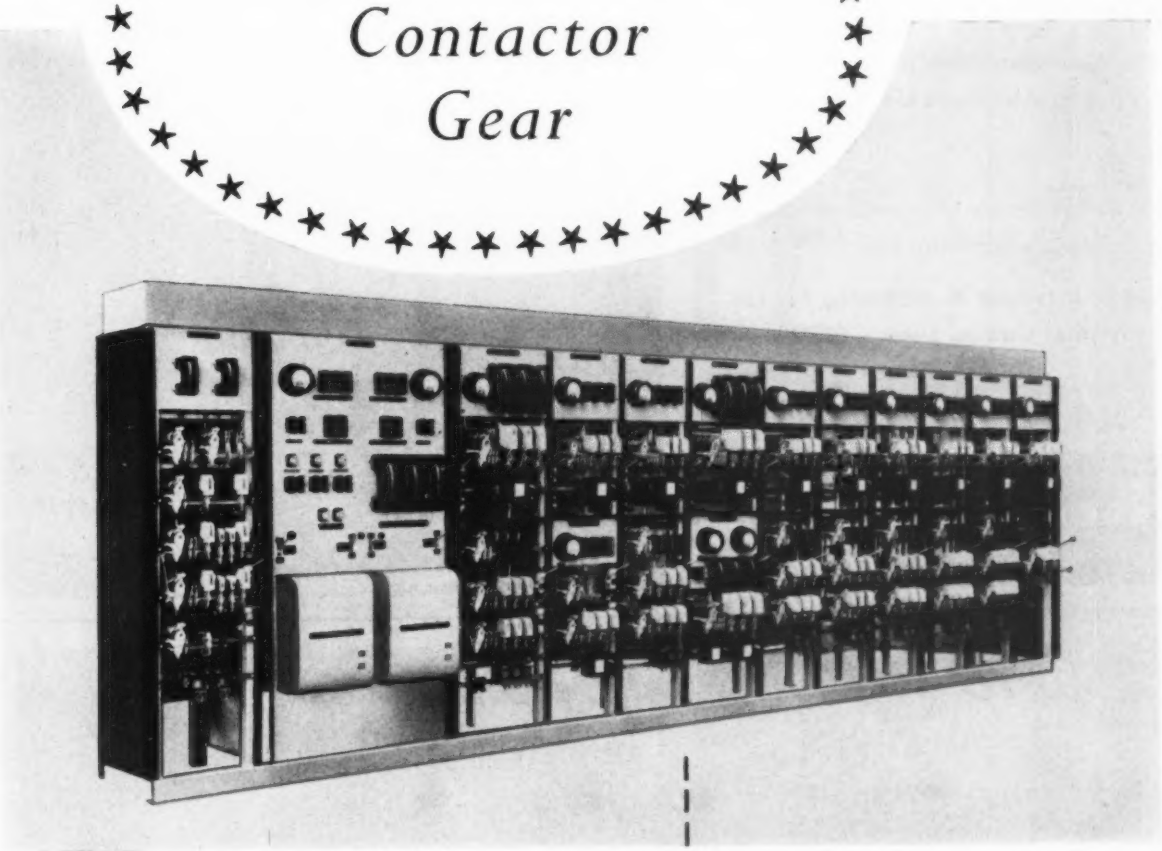

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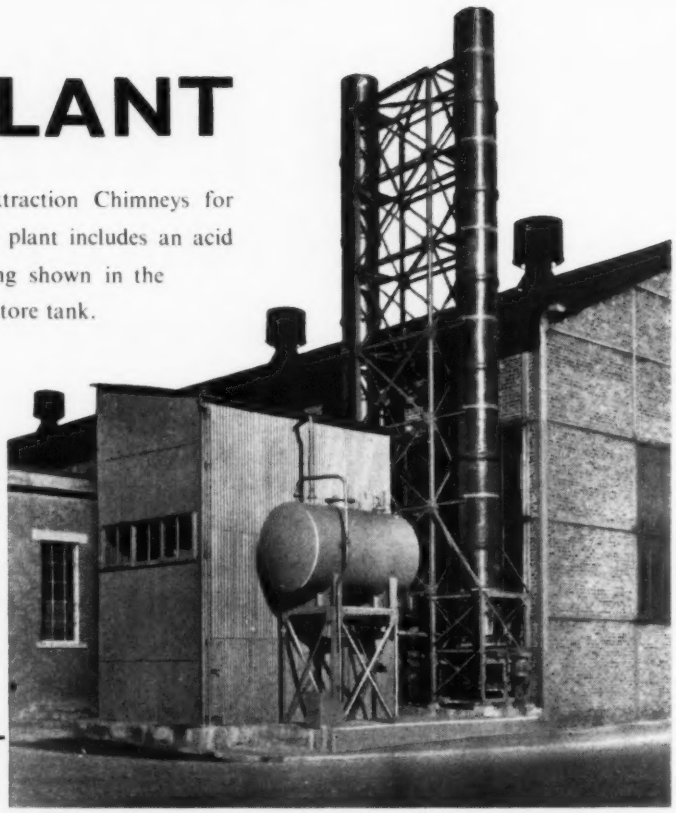

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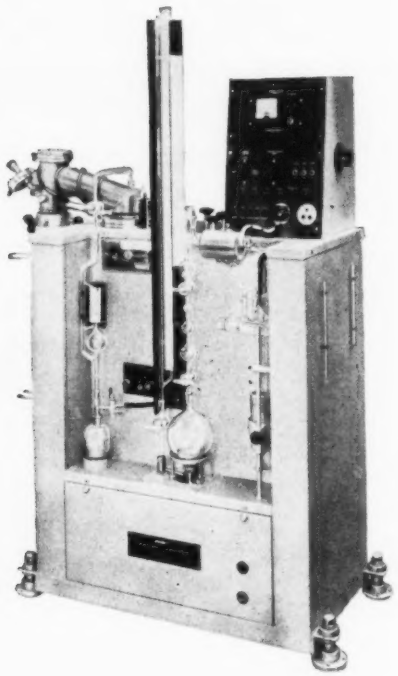

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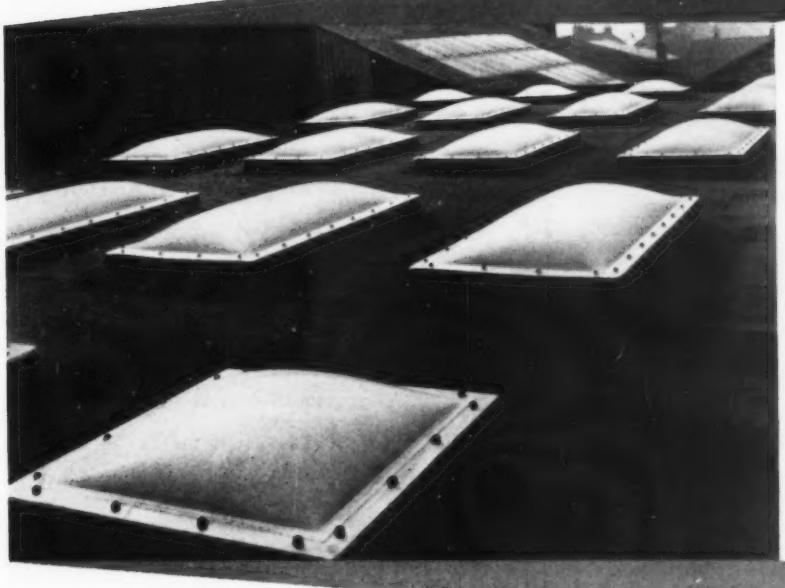

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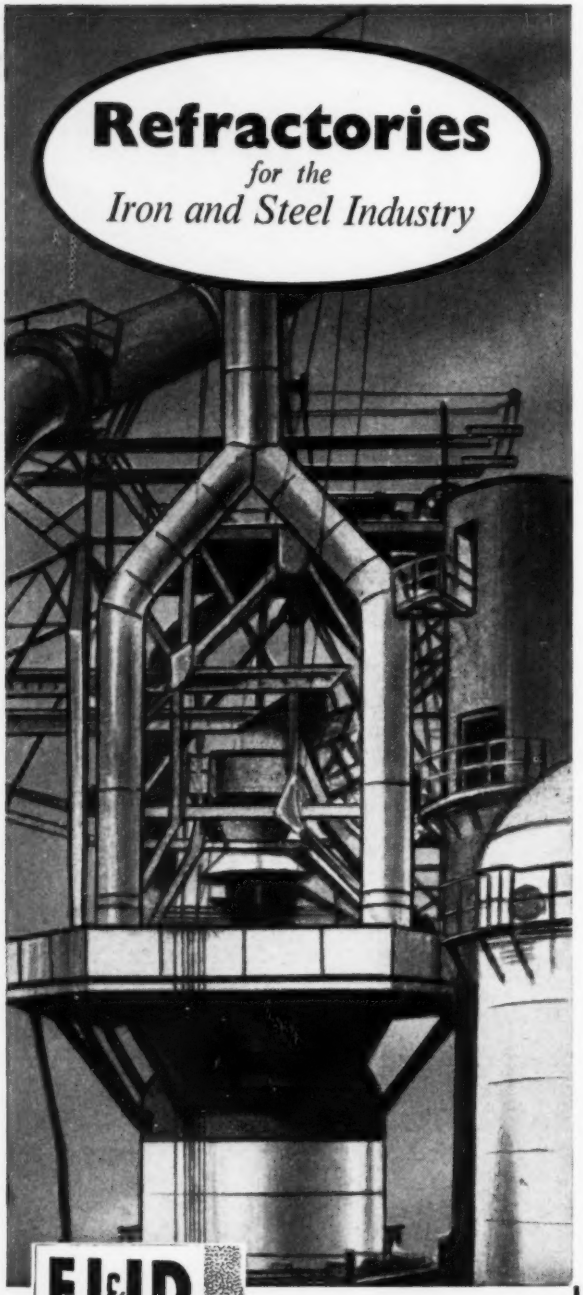

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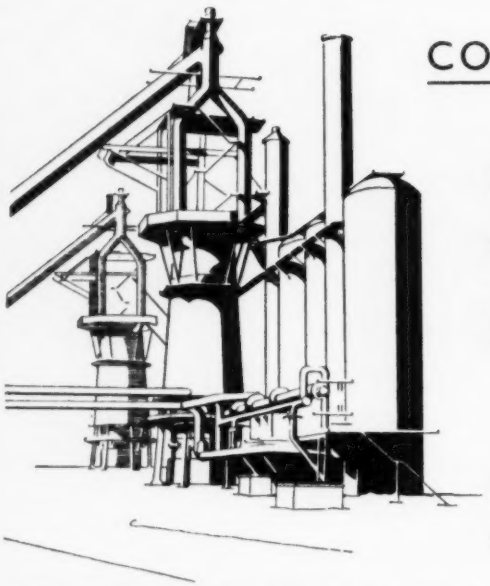

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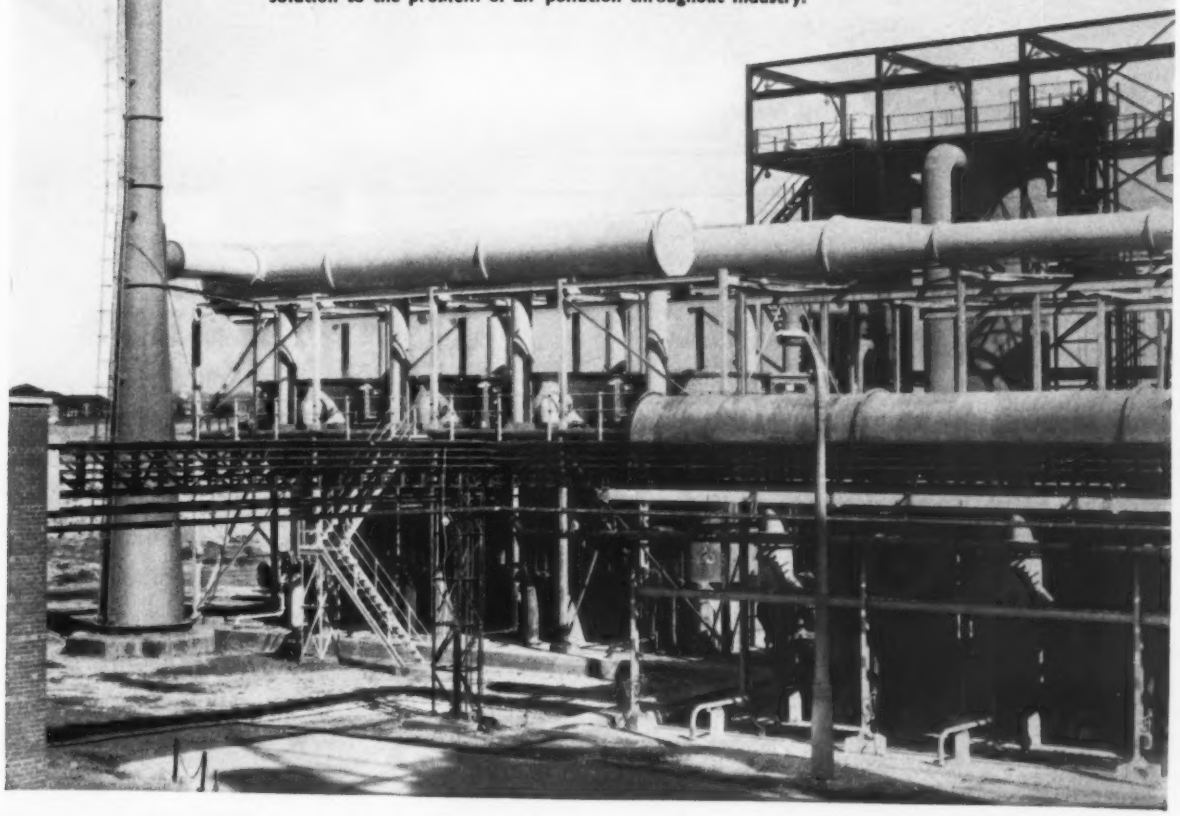

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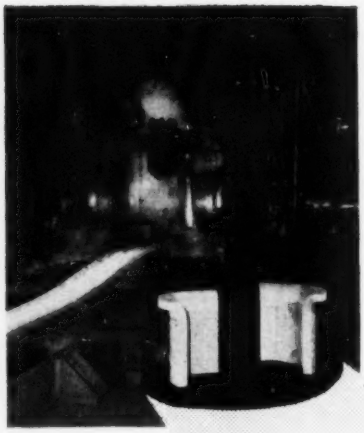

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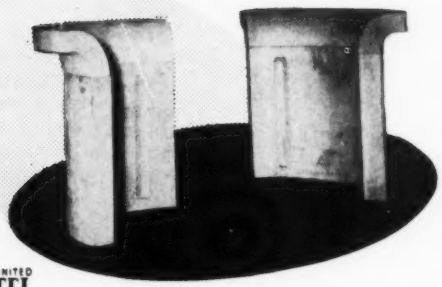

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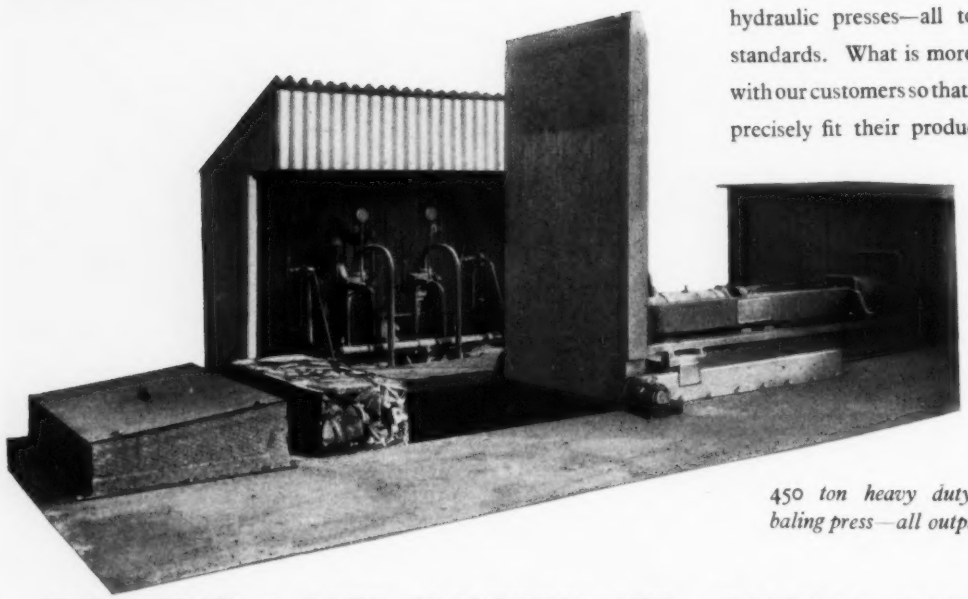

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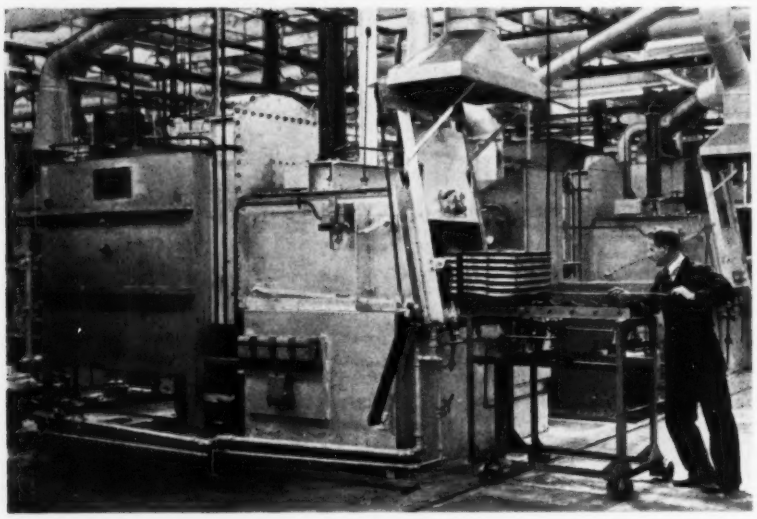

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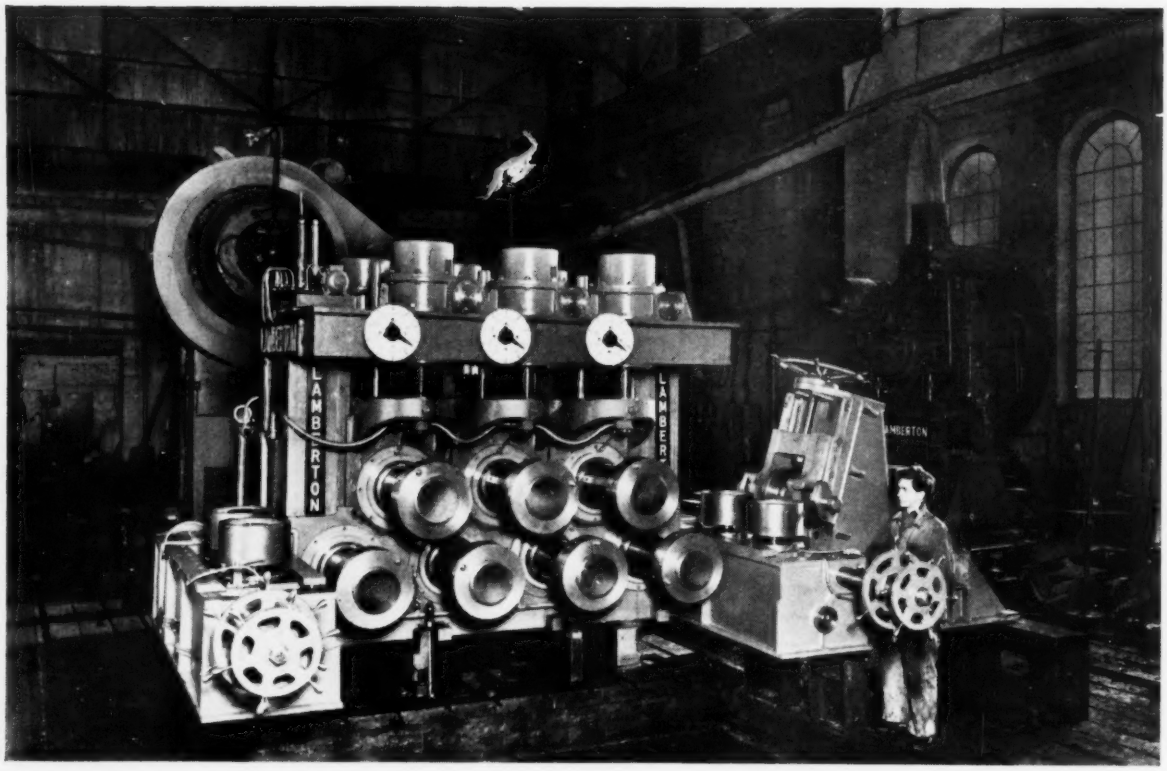

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